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THE SURGICAL MANAGEMENT OF PULMONARY COCCIDIOIDOMYCOSIS IN FOCALIZED LESIONS

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COCCIDIOIDOMYCOSIS is a highly infectious fungus disease with widespread endemic areas in West Texas, New Mexico, Arizona, Southern California, and the San Joaquin Valley of California. Almost all of the reported patients from North America have either visited or resided in one of these areas, but since vast numbers of soldiers were trained in these regions, patients who contracted the disease while in the Armed Services are now being discovered throughout the country.

The disease exists in a primary form which is usually self-limited and in a disseminated form which is fatal in almost one-half of the cases. The primary form is a disease of the respiratory system. It occurs from eight to twenty-one days following exposure.[1] Symptoms are present in only 40 per cent of the cases. If symptoms occur, they may be very mild and mistaken for a common cold or they may be severe with malaise, fever, chest pain, productive cough, and hemoptysis.[2, 3, 4] Even if there are symptoms, there may be no demonstrable chest lesion and only about one-fourth of the patients develop the disease in a form characteristic enough to be diagnosed clinically.[2] When a pulmonary lesion is present, it is at first inflammatory and if it heals at this stage there is no residual lung pathology. A few lesions progress from inflammation to suppuration and granuloma formation and since these lesions are destructive in nature they produce scar tissue when they heal. All of these lesions do not heal promptly. They may progress and spread to produce the disseminated form of the disease or they may form a focalized pulmonary infection either by remaining as a definite granuloma or by excavating to form a cavity. These focalized lesions may exist long after the initial acute pulmonary disease has subsided and are the most common form of the disease seen outside the endemic

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areas. Cavitation occurs in approximately 5 per cent of the clinically diagnosed cases.[3, 4] Most of the cavities probably close within several months if the patients are confined to bed. Some persist after prolonged bed rest, phrenic paralysis, pneumothorax therapy, or artificial pneumoperitoneum. Cavities may recur suddenly after closure has taken place, and even if cavitation persists, the patient can usually lead a normal life with few symptoms.[6, 7] Chronic focalized solid lesions are more common than cavitation during the acute phase of the primary disease, but most of these lesions regress completely or become inconspicuous on roentgenograms.[8] We have seen the large pulmonary granulomas less frequently than cavities.

Dissemination occurs in only one infection in 400.[2] When it does occur, it is usually as a progression of the primary form of the disease without significant regression of the initial symptoms. The symptoms become more severe with fever, weakness, and weight loss predominating. Suppurative and granulomatous lesions may spread in the lungs or throughout the entire body. Dissemination sometimes occurs after the primary infection has subsided, but apparently as the asymptomatic period grows longer, the probability of dissemination becomes less even in cases in which definite lesions persist.[2, 5]

PRESENTATION OF CASES

We have performed surgery on a total of thirteen patients having coccidioidal infections with focalized pulmonary lesions. Nine of the patients had persistent cavitation for which lobectomy was performed and four had rounded granulomatous lesions which were removed by wedge resection of the lung. All of the patients were soldiers or veterans and either had been stationed in endemic areas or had visited these areas. They were all white men; the youngest was 22 and the oldest 36 years.

The four patients with persistent granulomatous lesions in the pulmonary tissue were not ill at the time of operation. The lesion was discovered on a routine chest roentgenogram in each case, although two of the patients gave a history of episodes of pleuritic pain on the side of the lesion and had been bothered by mild chronic productive coughs. The other two patients had been asymptomatic. The diagnosis was not established preoperatively in any of the four cases, although coccidioidomycosis was suspected in three.

The nine patients with persistent cavitation were all symptomatic. They complained of a chronic cough which was productive except in one instance, but in no case was the cough severe and none of the patients produced more than one cupful of sputum daily. Eight of the nine patients complained of weakness and fatigue, often to a marked degree; it was the chief complaint in four of the cases. The pain was always of a pleuritic nature, was intermittent, and was usually severe while present. Dyspnea was complained of by six patients but it was mild in five of these cases and only moderate in the sixth. When hemoptysis occurred it was never severe but, on the other hand, there was usually more than tingeing of the sputum. All of the patients presenting this symptom had expectorated from one ounce to one cupful of bright red blood upon several

different occasions. Three patients had chronic low-grade fever with periods of intermission but elevations above 101° F. were rare. Weight loss was a symptom in the same group that had fever; they had averaged approximately fifteen pounds loss. Six of the patients complained of symptoms which would not allow normal activity. These incapacitating symptoms had been evident from twelve to sixty-four months and hospitalization had been necessary an average of one year prior to surgery. All six of these patients complained of a persistent weakness and fatigue, and five had frequent episodes of hemoptysis. The chief complaint in four of the patients was ease of fatigue, while the other two complained of frequent episodes of hemoptysis in which 50 to 250 c.c. of blood would be expectorated. In addition, four of these patients had frequent episodes of pleuritic pain and three had chronic low-grade fever. Two case histories illustrate the characteristic course of the disease in patients having lobectomy.

CASE 1.—This 29-year-old soldier was born in Bowie, Texas, but was never in an endemic area until early in 1946 when he visited West Texas. While in this area he was in a sandstorm. In July, 1946, he had the sudden onset of pleuritic pain in the left chest and produced some blood-tinged sputum. A roentgenogram of the chest was reported as normal and the symptoms regressed in a few days. He continued to have pleuritic pain intermittently and a chest x-ray picture taken in November, 1946, showed cavitation in the left mid-lung field. He was hospitalized, the pain increased in intensity, and despite bed rest the cavity increased in size and the hemoptyses became more frequent and more severe. On several different occasions he produced as much as one cupful of bright red blood. He developed a cough which was productive of 15 to 30 c.c. of gray sputum daily. Many sputum examinations were negative for acid-fast bacilli but positive cultures of *Coccidioides immitis* were obtained repeatedly. Both the tuberculin and the coccidioidin skin tests were positive. His poor response to bed rest over a period of seven months was thought to be sufficient reason for resection of the lesion, and the left upper lobe was removed July 1, 1947. At operation pleural adhesions were noted overlying the area of cavitation.

The pathologic examination of the excised lobe revealed a cavity which measured 6 by 3 by 3 cm. A bronchus communicated with the cavity but this was plugged with necrotic tissue and the cavity contained air under pressure. The inner wall was of a caseous and necrotic nature and there were several areas of granulation tissue in the wall. The outer wall of the cavity was composed mainly of fibrous tissue. There were many small nodules palpable throughout the lung tissue. On microscopic examination mycelial forms of the fungus were seen but there were no spherules present. There was a chronic granulomatous pneumonitis in the surrounding lung, and nearby bronchi were involved in a chronic suppurative bronchitis. The multiple small nodules palpable in the lung were granulomatous foci but no fungi were seen in any of them. He had some atelectasis of the left lower lobe on the second postoperative day but he responded well to bronchoscopic aspiration. The lower lobe expanded to fill the entire left thoracic cage and he was returned to duty two months following surgery. Ten months after operation the patient was asymptomatic and doing general military duty.

CASE 2.—This 24-year-old white man was born in Minnesota. He was stationed in an endemic area of Arizona from October, 1943, until March, 1944. One year after leaving this area he developed a dry cough and two months later he first noticed blood-tinged sputum. In July, 1945, while overseas there was a gross hemoptysis and he was hospitalized. At that time he was ten pounds underweight and he complained of weakness and ease of fatigue. X-ray examination revealed a cavity in the right upper lung field measuring 1.5 to 2.5 cm. He arrived at Fitzsimons General Hospital Aug. 20, 1945. At that time there was no hemoptysis but he still had a chronic nonproductive cough and complained of marked fatigue.

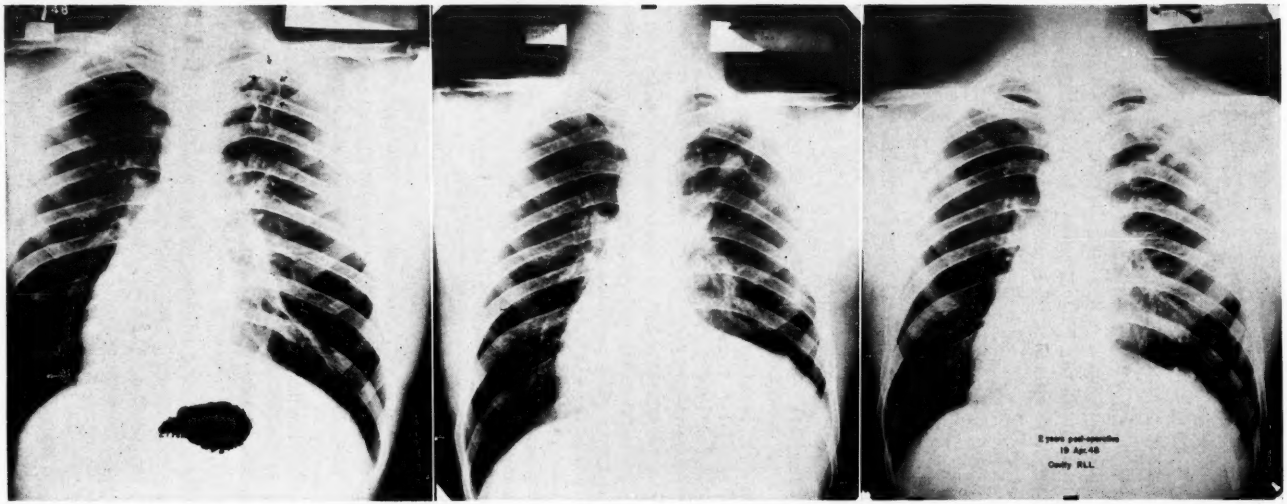

Fig. 1. Fig. 2. Fig. 3.

Fig. 1 (Case 2).—Cavity, right upper lobe.
Fig. 2 (Case 2).—Two months postoperatively; suggestive lesion in upper lung field which excavated two years later.
Fig. 3 (Case 2).—Cavity, two years postoperatively.

On repeated examinations *C. immitis* was cultured from the sputum and no acid-fast bacilli could be found. He was transferred to another hospital in August, 1945, where despite bed rest the sputum again became blood tinged, and on three occasions in the next four months he had episodes of gross hemoptysis. He continued to have a chronic low-grade fever. He was transferred back to Fitzsimons General Hospital Feb. 27, 1946 (Fig. 1). At this time the cavity was unchanged, the coccidioidin skin test was weakly positive, and the blood serology* was reported as being positive but of low titer, indicating that the process was well localized. Because of the persistence of severe symptoms after nine months hospitalization, it was decided that a lobectomy should be performed. The right upper lobe was removed April 22, 1946 (Fig. 2). At the time of operation pleural adhesions were encountered over the area of the cavity. No abnormality was noted in the remaining lower and middle lobes. On gross examination the cavity measured 2.5 by 2.5 by 3.5 cm. It was empty except for a few drops of mucoid material. Direct examination of this material revealed mycelial forms of *C. immitis* with chlamydospores, and cultures were positive for *C. immitis.* On examination of the prepared slides both forms of the fungus were seen. There were numerous miliary nodules in the surrounding lung tissue which were composed of central giant cells with surrounding epithelioid cells. No fungi were observed in these areas. There was much fibrosis about the lesion. The lining of the cavity was composed of squamous metaplasia epithelium, ciliated epithelium, granulation tissue, and caseous material. There was a bronchitis involving the bronchi communicating with the cavity. The postoperative course was uneventful. The remaining right lung expanded to fill the entire right thoracic cage. Two months following surgery he was asymptomatic and had gained ten pounds. He remained asymptomatic until March, 1948, almost two years after the lobectomy, when he began to tire easily and have a productive cough. He was hospitalized after producing bloody sputum, and chest roentgenograms showed a cavity in the right lower lobe measuring 3 cm. in diameter. No acid-fast bacilli were discovered in the sputum, but many cultures of *C. immitis* were obtained (Fig. 3). A review of the immediate postoperative roentgenograms reveals a circumscribed area of increased density in the re-expanded lower lobe which is the site of the present cavitation.

These two cases are representative of the six cases with cavitation and debilitating symptoms. The other four patients gave similar histories. Surgery was accomplished without difficulty and there were no immediate complications. Three of the nine patients had symptoms which had been noticed but were not severe enough to keep them from their work. One of these cases is interesting because serial x-ray views were obtained from the time the acute pulmonary infection started. A cavity was seen to develop and then close, only to reopen after two years. The latter case history is as follows:

CASE 3.—This 31-year-old white man, a soldier, made frequent trips into the lower San Joaquin Valley during the summer of 1941. In July, 1941, he developed a pleuritic type of pain involving both sides of the chest and reported to the hospital for treatment. X-ray examination showed a small diffuse lesion in the apex of the right lung and another small lesion in the left lower lung field which soon cavitated (Fig. 4). After two months he was discharged from the hospital and returned to his work as an x-ray technician. The only symptom was a mild chronic productive cough. Frequent roentgenograms were taken and in 1942 the cavity in the left base was not discernible (Fig. 5). In 1943 the lesion in the right apex was more discrete. In 1944 the lesion in the left lower lobe suddenly reappeared and by 1945 it was larger and showed a central area of rarefaction (Fig. 6). In February, 1947, he was hospitalized because of severe pleuritic pain and at this time there was an area of cavitation 2.5 cm. in diameter in the left lower lobe. The small nodule in the right apex had not changed in appearance in four years. No acid-fast bacilli were revealed after many sputum examinations but there was one positive culture for *C. immitis*

*Performed by Dr. C. E. Smith.

in thirteen examinations. Both the tuberculin and the coccidioidin skin tests were positive to a marked degree. Blood serologic examinations* for coccidioidomycosis were negative. A short trial of artificial pneumoperitoneum produced no effect on the cavity. He remained asymptomatic except for a chronic cough productive of small amounts of sputum and intermittent chest pain. A lobectomy was advised because of the long-standing cavitation. This operation was performed Oct. 2, 1947. At the time of surgery, pleural adhesions were

Fig. 4. Fig. 5.

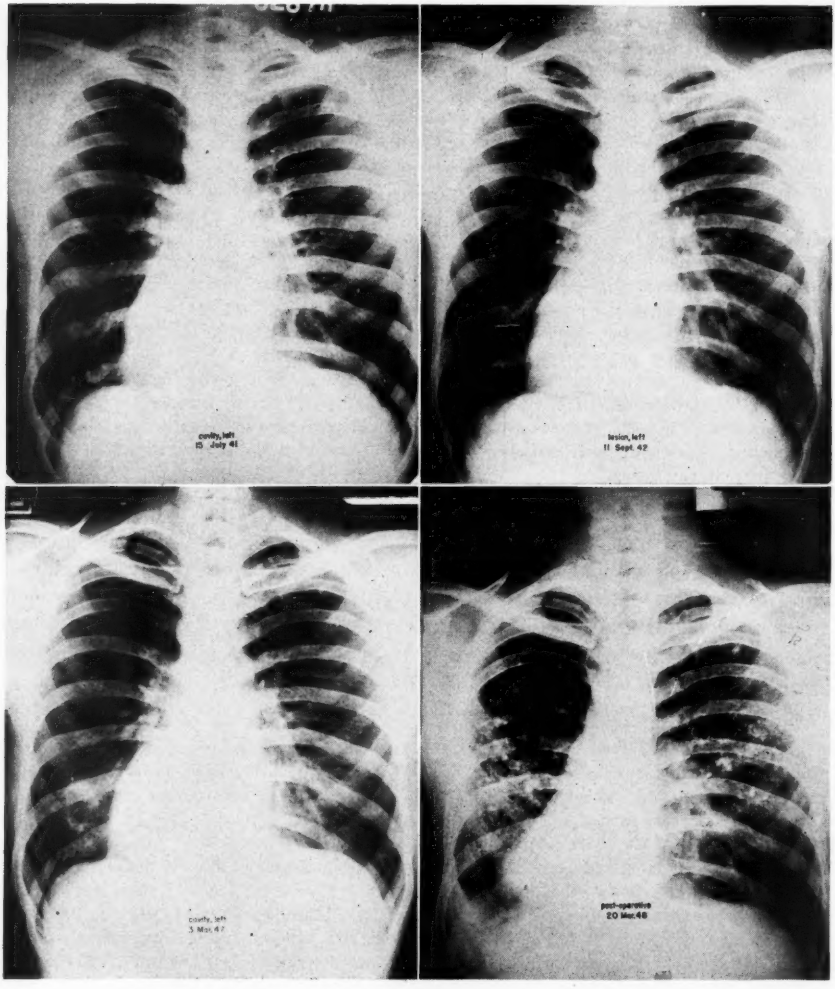

Fig. 6. Fig. 7.

Fig. 4 (Case 3).—Lesion, right upper lobe; cavity, left lower lobe.
Fig. 5 (Case 3).—Cavity, left lower lobe not discernible.
Fig. 6 (Case 3).—Cavity, left lower lobe is larger.
Fig. 7 (Case 3).—Five months postoperatively, residual lipiodol.

*Performed by Dr. C. E. Smith.

noted over the area of the cavity. There was no gross involvement of the upper lobe. Upon pathologic examination it was discovered that the cavity contained spherules of *C. immitis*. The cavity was surrounded by a fibrous zone 0.2 cm. thick and was lined by an area of caseation necrosis which at some points extended through the fibrous walls. Scattered about the cavity were miliary granulomas composed of epithelioid cells and Langhans' giant cells. Spherules of *C. immitis* were found in these satellite granulomas. He had an uneventful postoperative course and was returned to full military duty three months after surgery. He is asymptomatic seven months after surgery and there is no evidence of progression of his disease (Fig. 7).

Another patient with only moderate symptoms had a routine chest x-ray picture made and was discovered to have an area of cavitation in the upper lobe on the right. He gave a history of having had frequent colds and a moderate cough associated with increased ease of fatigue and intermittent chest pain over a period of four to five months. He was hospitalized and the diagnosis of coccidioidomycosis established by a positive culture of *C. immitis* from the sputum and by a positive coccidioidin skin test. There were no changes in his symptoms or in the size of the cavity after thirteen months of hospitalization, and a lobectomy was advised. Lobectomy was performed on another patient who had no symptoms other than a chronic nonproductive cough. He had a cavity in the left upper lobe measuring 6 cm. in diameter which had thick walls and contained a fluid level.

The round granulomatous lesions were excised with ease in every instance. Only one case had pleural adhesions and these were limited to the area of the lesion. The nodules were all situated near the periphery of the lung although the lesion was actually subpleural in only one. The superficial location allowed them to be easily removed by wedge resection.

All nine of the lobectomies were performed without technical difficulties. There were pleural adhesions overlying the areas of cavitation in all of the cases but there were few adhesions over the rest of the lung. There was little hilar involvement and dissection was accomplished with relative ease. Only one case offered a technical problem. A large cavity 10 by 4 by 3 cm. was found to have crossed the interlobar fissure so as to involve the posterior portion of the right upper lobe as well as the entire dorsal division of the right lower lobe. In this case the right lower lobe was removed along with a segment of the right upper lobe.

PATHOLOGY

The granulomatous lesions were removed from the left upper lobe in three cases and from the right lower lobe in the remaining case. The pathogenic organism was seen microscopically in three of the lesions and cultured from the fourth. The nodules varied from 2 to 4 cm. in diameter. Two of the four lesions were solid. One had a liquified center and the other showed a central area of cavitation which communicated with a bronchus (Figs. 8 and 9). In a typical granuloma there is caseation toward the center with a very gradual change to an area where the caseation is intermingled with a fibrous stroma. This area usually contains recognizable alveoli and occasional giant cells. Near the periphery of the lesion the fibrous element becomes more dense and some hyalinization is present. Occasional giant cells are also seen in this area. Normal

lung with little distortion usually surrounds the lesion but sometimes the fibrous element extends into the surrounding alveoli. In the case in which there was bronchial communication there was also a surrounding area of chronic interstitial pneumonitis with infiltration of plasma cells, eosinophiles, and lymphocytes, and at some distance from the nodule there was an area of suppurative bronchitis with surrounding pneumonia. Two of the specimens had smaller nodules intimately connected with the larger nodule but in only one were spherules seen in these satellite granulomas.

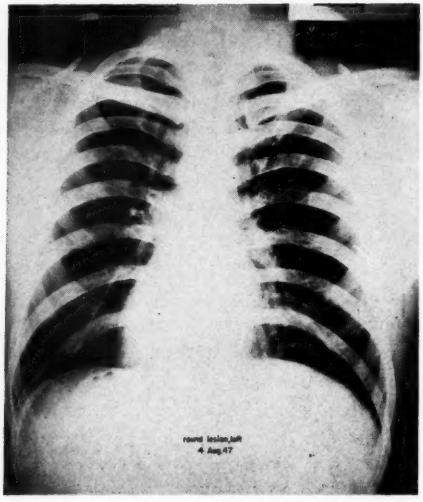

Fig. 8.—Granuloma, left upper lobe.

The cavitation involved the right upper lobe in five cases, the left upper lobe in two, the left lower lobe in two, and the right lower lobe was involved in one patient along with the right upper lobe involvement. At least one form of the pathogenic organism was seen in every case; the mycelial form was observed in six specimens and the spherule form in six. Three of the cavities contained air under pressure and they all contained a small amount of fluid. Satellite nodules were palpable and visible about the cavity or even throughout the involved lobe in all except two cases. The pathology of the cavity is fairly consistent. There is an outer fibrous layer 0.1 to 0.5 cm. thick which makes the area of cavitation feel firm in the intact specimen. The lining appears rough and irregular and is composed of a grayish-yellow caseous layer 0.2 to 0.5 cm. thick. Small areas of granulation tissue with evidence of recent hemorrhage are frequently seen projecting into the cavity. On microscopic examination the lining of the cavity is seen to consist mainly of a surface zone of necrotic tissue with few identifiable cells. Both forms of the fungus are frequently seen clinging to this area. In some cases there are areas of granulation tissue, stratified squamous epithelium, or ciliated stratified squamous epithelium in the lining. This inner layer blends into a necrotic zone in which there is loosely interspersed a fibrous stroma with macrophages and eosinophiles. This is surrounded

by a more dense fibrous zone into which protrude fibrous bands, many of which are coarse and collagenous. This zone contains many plasma cells and eosinophiles as well as lymphocytes and occasional giant cells. The fibrous zone extends into surrounding lobules obliterating alveoli. In seven of the nine cases

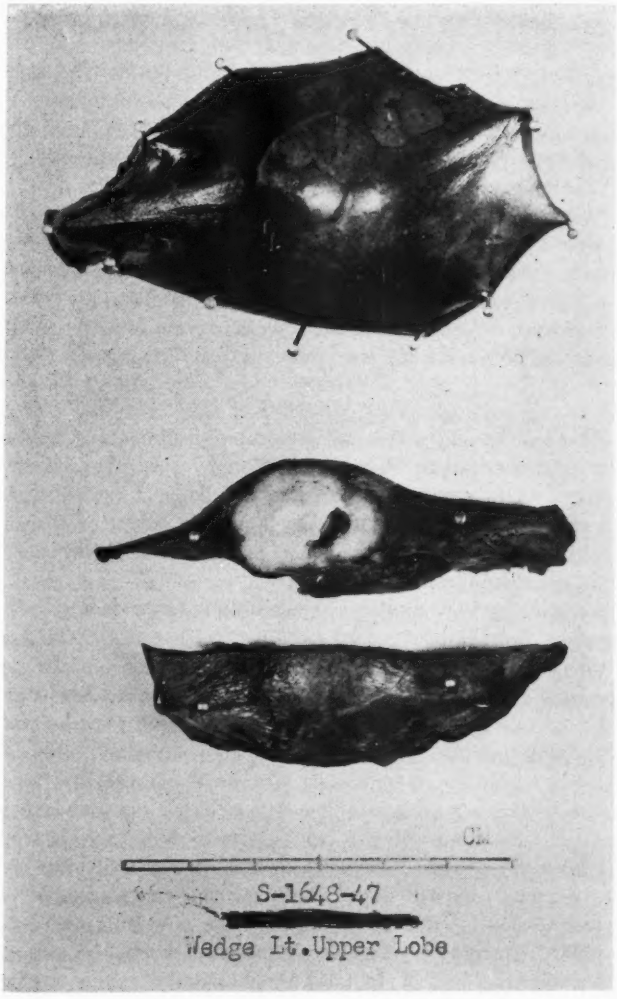

Fig. 9.—Excised granuloma with central area of cavitation which communicated with a bronchus.

there were satellite lesions consisting mainly of tubercles formed by epithelioid cells or epithelioid cells surrounding giant cells and spherules were seen in these lesions in two of the specimens. There were also areas of chronic pneumonitis, caseous lobular pneumonia, and caseation necrosis surrounding the cavities.

Most of these lesions were near the cavity but sometimes they were found a considerable distance away. It is interesting to note that a single regional lymph node was involved in only one case, although next to the lung this is the most commonly involved site in disseminated cases.

POSTOPERATIVE COURSE

The postoperative course of the segmental resections was uneventful in every case. There were no complications. The nine patients having lobectomies had much the same course as would be expected in a similar group with bronchiectasis. There was no incidence of bronchopleural fistula or empyema. One patient developed diffuse mottling throughout the opposite lung on the day following lobectomy. This process increased in the next few days but was not accompanied by any toxicity. Only a small amount of sputum was obtained when the patient was bronchoscoped and no *C. immitis* colonies grew when this material was cultured. Since dissemination was feared, a specimen of blood was sent for serological examination.* Both the precipitin and complement fixation tests were negative. The lesions cleared progressively and were entirely absent two months after surgery. He was well one year after surgery.

SUMMARY OF RESULTS

The four cases having wedge resection of granulomatous lesions have been observed for an average of fourteen months following surgery. The first patient was operated upon thirty-five months ago and the last case only four months ago. None of them had symptoms other than pain near the site of operation. They are all at work and there has been no evidence of any other lesion on postoperative roentgenograms.

The nine cases having lobectomy for coccidioidomycosis with cavitation have been followed an average of eighteen months after surgery. The first operation was done thirty-two months ago and the last was three months ago. All patients have been contacted recently except one whose address has been lost; he was last seen twenty months after surgery at which time he was well. Six of the nine patients have been benefited by the surgery in that their symptoms have been markedly improved or abolished and there is no evidence of active disease in the remaining lung tissue. These six men are all working full time. Another patient still has troublesome symptoms. He is able to work full time doing light delivery work but he tires easily. The last x-ray picture taken at Fitzsimons General Hospital six months ago showed no evidence of any pulmonary lesion. Two of the patients are now in worse condition than they were prior to surgery. One of these patients developed pulmonary tuberculosis with cavitation in the right lower lobe three months after resection of the right upper lobe. Before surgery tuberculin skin tests were negative in first and second strengths and the sputum had been negative for acid-fast bacilli on twenty-one smears, ten cultures, and two guinea pig inoculations. The pathologic examination of the excised lung revealed the typical lesion of coccidioidomycosis with large numbers of spherules visible in the cavity, in the

*By Dr. C. E. Smith.

walls of the cavity, and in the satellite granulomas. There was no evidence of tuberculosis. There was a patent bronchus communicating with the cavity. The patient has been hospitalized fourteen months for the tuberculosis and the sputum has been negative for acid-fast bacilli for eight months, but there is still a question of cavitation in the right lower lobe. The other patient had severe symptoms and was definitely suffering from a chronic and debilitating disease at the time of surgery. He had almost immediate relief from the symptoms and gained weight rapidly following resection of the right upper lobe. He was asymptomatic for two years, but suddenly the symptoms returned, and he is now almost as ill as before operation. He has a 3 cm. cavity in the right lower lobe, and the sputum is again positive for *C. immitis* (see Case 2).

DISCUSSION

The management of chronic granulomatous lesions of coccidioidomycosis appears to be simple. The diagnosis can seldom be made with certainty and it is a sound policy to remove these tumors for no other reason than to establish a diagnosis and rule out the possibility of a more dangerous lesion. Even if the diagnosis is without question, it seems that the threat of cavitation or dissemination should be abolished while the lesion is in a more focalized form. Even though dissemination from these foci must be an unusual occurrence, the operative removal is relatively simple and seems to be the safer course.

The problem of dealing with persistent cavitation is a difficult one. Most of these lesions do not produce symptoms or debilitation and patients with cavitation have been known to do hard work for years with no apparent ill effect. However, even when no symptoms exist, these cavities should not be regarded as innocuous. They are usually near the periphery of the lung and in four cases presented in a previous paper they have ruptured causing bronchopleural fistula, coccidioidal empyema, and nonexpansile lung.[9] There is also evidence that these foci of infection may be a source of dissemination, although there is little likelihood of this taking place long after the initial infection. From the standpoint of epidemiology there has been no record of a proved direct human transmission of the disease and for this reason patients with open cavities are not isolated. However, the reason commonly proposed for the lack of human transmission has been that the spherule form of the organism, which is usually seen in the sputum, exudates, and diseased tissue of infected patients has a low infectivity, while the highly infectious mycelial form grows only in an external environment. It is to be noted that six of the cavities removed contained mycelial forms. Either the disease will be transmitted when individuals with open cavities return to their families outside of endemic areas or there is some other factor in the transmission of the disease. In spite of these possible complications, our experience in the management of this small group of nine cases suggests that pulmonary resection should be reserved for those patients having definite symptoms over a long period of time. In the few cases presenting incapacitating symptoms and evidence of chronic debilitating disease after prolonged hospitalization, pulmonary resection is indicated. It may be that a longer period of hospitalization before and after surgery would be beneficial.

CONCLUSIONS

1. Four patients with focalized granulomatous lesions have been treated satisfactorily by wedge resection of the diseased portion of lung. We feel that these lesions should be removed in order to rid the patient of a possible source of dissemination and in order to rule out the possibility of a more malignant process which might have an identical roentgenologic appearance.

2. Coccidioidal cavities have been removed by lobectomy in nine cases. Lobectomy should be reserved for those patients who have distressing symptoms over a period of many months.

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DISCUSSION

DR. DONALD L. PAULSON, Dallas.—(Slide.) This patient was admitted to the hospital in April, 1945, because of hemoptysis. Roentgenograms revealed a thin-walled cavity in the right upper lobe. While he was under observation the cavity ruptured into the pleural cavity, resulting in a pneumothorax with fluid. This was aspirated and *C. immitis* was found in the fluid. A diagnosis of coccidioidomycosis of the lung and pleura was made. Attempts to expand the lung were not successful and a decortication was done. A thickened fibroblastic membrane was found overlying the lung and the parietal pleura. This membrane was removed, and a segmental resection of the posterior segment of the right upper lobe was done to remove the cavity. The organisms of coccidioidomycosis were found in the fibroblastic membrane.

The patient had an uneventful convalescence following this surgery. He has had no further symptoms and is now leading a normal life. The second slide shows a roentgenogram made in 1948 which reveals complete expansion of the lung with no evidence of residual disease.

DR. FORRESTER RAINE, Milwaukee.—I am rather surprised that in these cavities which were treated by resection, only three were found in which the mycelium was growing on the walls. Most patients with coccidioidomycosis recover without difficulty, but we had one similar to these in which mycelium was growing on and in the wall of the cavity. This, I think, accounts for the very copious sputum as well as repeated hemoptysis which is not seen in the granulomas containing the endospore form of the fungus.

These slides show a patient operated upon by Dr. Wilson Weisel at the Veterans' Hospital in Milwaukee. The first slide shows the cavity small in 1945, the next larger in

1946, and the next several times larger by 1947. A lobectomy was performed in 1948 and the final slide shows the specimen with the large cavity and possibly you can see the roughness of the wall where pure culture of the mycelium was obtained.

DR. ROBERT R. SHAW, Dallas.—The increasing awareness of this disease in our part of the country has posed a difficult problem in the differential diagnosis of tumors within the lung. There is a prevalence of skin testing for both the coccidiodes or/and histoplasmosis. Sometimes the internist or the physician carrying out the skin testing is quite satisfied with the positive reaction in explaining the presence of a shadow within the lung field. In two patients with carcinoma in the past two years this has led to a too-long period of waiting with the result of inoperability by the time the true diagnosis was made. So here again, as with virus pneumonia and unresolved pneumonia, we must be very circumspect in explaining shadows that appear in the lung fields on the basis of a nonspecific skin test.

I want to show a specimen of a left upper lobe that was removed as a result of a shadow found in a survey. This subsequently proved to be a coccidioidal granuloma with daughter granulomas within the same lobe. I think these lesions should be removed for their own presence, regardless of the fact that they may be found because of a suspected diagnosis of carcinoma. This man denied having symptoms at the time the survey was taken, he was a food handler—but after the lobectomy had been completed and within a month following removal of this lobe, he volunteered the information that he felt entirely different now than he did before surgery. He had a feeling of well-being now that he had not had before. This man had been present in an endemic area for only approximately six months, during which time he was visiting in El Paso. We do not consider coccidioidal mycosis to be endemic in the regions of Central Texas, but we must be continually on the alert for this condition. The coccidioidal granuloma is, of course, very similar to the tuberculoma and if an accurate diagnosis can be made I think it becomes difficult to advise the patient just what should be done, if he denies having any symptoms whatsoever. I am of the opinion, however, that even with a proved diagnosis these granulomas should be removed.

DR. W. L. ROGERS, San Francisco.—Until recent years we in California and the Southwest had a monopoly on this interesting clinical entity. I think it is quite obvious to all of us here that that condition no longer exists. I believe this excellent review is quite timely, and it is my belief that this is the first occasion this condition has been presented before this surgical association. I would like to confine my few words to the latent residual cavity. In our experience that has been the most frequent of the late complicating conditions with which the clinician is confronted. To give you briefly an idea of what the average clinician in our area may expect in the ordinary course of these residual cavities, let us consider a theoretical 100 cases. We may assume that sooner or later approximately 40 per cent of this group will close spontaneously. Approximately 20 per cent will remain relatively symptom-free. The remaining 40 per cent will require active therapy either because of increasing size or because of recurrent severe hemoptysis. I might say at this time approximately 70 per cent of these residual cavities at one time or another will give a history of small hemoptysis and approximately 10 per cent also will give a history of secondary infection. We feel a trial by conservative collapse measures, such as pneumothorax or pneumoperitoneum, should be afforded this group. Pneumoperitoneum may be occasionally supplemented by a temporary phrenic if that seems necessary. Collapse measures are effective in approximately 90 per cent of this residual group. Collapse therapy should be maintained for about one year. The remaining 10 per cent obviously should come under surgical consideration.

In closing I should like to mention two other points. If one is not familiar with this disease, particularly so far as laboratory work is concerned, we must be very careful, indeed, to warn laboratory technicians of the possible danger involved. In Dr. Smith's laboratory at Stanford, no technician is employed who does not have a positive coccidiodin. On one occasion a visiting physician merely passing through the laboratory contracted the disease. In San Francisco, because of the availability of Dr. Smith's laboratory, our other private institutions prefer not to handle these cultures at all.

Also, I would like to ask Colonel Forsee or Dr. Greer their feeling regarding the granting of 100 per cent permanent disability rating to these veterans who have been subjected to lobectomy irrespective of how well they may do clinically. This appears to me to be an injustice, especially when the operation is performed for a curable disease.

DR. O. A. ABBOTT, Atlanta.—I hesitate to go on with this discussion, but we did encounter a very interesting and rather unusual complication of this disease at our local Veterans Facility. The patient was a physician's son, 24 years of age, and had an acute coccidioidal pneumonitis four years before when stationed in San Joachin Valley territory. The pulmonary lesion cleared completely, and then he developed typical signs of constrictive pericarditis, and he was considered for surgery. The sedimentation rate was extremely high and the skin tests for coccidiodomycin very strong, also the skin test for tuberculin was very strong. We thought it important to utilize the additional safety precaution of giving the patient streptomycin because of the reports of the possible value of this drug in coccidioidomycosis. This was done and in one month's time the sedimentation rate was normal, and a pericardiectomy was performed. The pericardium contained the typical spherules but no mycelia were seen. There has been no evidence of recurrence of the lesion since this surgery.

COL. FORSEE.—I wish to thank the members of the Association who have discussed this paper and presented questions in which we are very much interested. There were six of the cases with cavitary lesions that had mycelial forms present, rather than three. The surgical therapy which has been carried out in these cases seems to be the best we have available at the present time; however, it leaves much to be desired. Follow-up letters that we have received from all of these patients indicate a degree of residual chronicity of the disease somewhat out of proportion to that usually seen after such operative procedures. It has been our practice to have these patients hospitalized for prolonged periods before they are operated upon. We now wonder, particularly since this one patient has returned with a cavity in the remaining lung tissue, if it would not be desirable to treat these patients with prolonged bed rest after surgery, particularly those having cavitary lesions.

In the excision of granulomatous lesions, just one word of warning, that is, that there should be a wide resection with normal lung tissue excised because of the danger of adjacent granulomatous daughter involvement about the original granuloma.

We have no answer to the problem of disability following lobectomy. We have returned several of these patients to duty following lobectomy, and that is our practice at the present time. In a simple, uncomplicated lobectomy for other than neoplastic or tuberculous disease our policy is to return the soldier to general military duty. Whether or not we are correct in this we do not know, and we would be very much interested to know what the Veterans Administration does in the matter of disability. I am sorry I cannot answer your question, Dr. Rogers, except to say that we have felt that the mere absence of a lobe of a lung certainly does not constitute a disability for which the individual should receive retirement pay or pension benefits for the remainder of his life.

BLOOD VOLUME AND EXTRACELLULAR FLUID CHANGES DURING THORACIC OPERATIONS

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THE first measurements of the amount of blood lost during operations were made by Gatch and Little[1] in 1924. Blood loss was estimated by determining colorimetrically the acid hematin concentration in the washings of blood-soiled sponges and instruments. The authors pointed out that blood loss was often greatly in excess of the surgeon's estimate. Losses of 500 to 700 c.c. were well tolerated by individuals in good physical condition, while losses greater than 1,000 c.c. were usually accompanied by serious effects. Additional colorimetric studies of blood loss during major abdominal operations have substantiated these observations.[2, 3] White and Buxton[4] using the same method found an average blood loss of 700 c.c. for thoracoplasty stages and 1,500 c.c. for lobectomy. Nadal measured blood loss during orthopedic operations,[5] and blood loss during neurosurgical procedures was studied by White and associates.[6] The colorimetric method yielded figures which were 1 to 7 per cent[5] and 13 to 14.6 per cent[4] below the actual values when a known quantity of blood was washed from soiled sponges or linen. Shock did not become clinically evident until the patient had lost 20 per cent of the normal blood volume or approximately 1,200 c.c. Patients losing less than 20 per cent of their normal blood volume were not likely to develop clinical evidence of shock unless the loss had been rapid. These authors urged immediate replacement of blood during operation and warned against delay until shock had become evident.

Wangensteen,[7] in 1942, described a gravimetric method for estimating blood loss during operation. Blood loss was measured by determining the difference in weight between dry gauze sponges before and immediately after use. By this means the surgeon can have an accurate estimate of blood loss at any time during the operation. Baronofsky, Treolar, and Wangensteen,[8] using both the colorimetric and gravimetric methods, found an average blood loss of 1,324 c.c. for lobectomy and 1,534 c.c. for pneumonectomy; values obtained with the gravimetric method were 10 per cent higher than values obtained with the colorimetric method.

Gibbon, Gibbon, and Kraul[9] have demonstrated that a blood transfusion of a size well tolerated by normal animals may produce pulmonary edema in cats in which there has been an acute reduction of pulmonary tissue. Thornton and associates[10] have demonstrated the role of the rate of administration of massive transfusions after pulmonary resection in the development of pulmonary edema in dogs. Over-replacement with blood, either during or imme-

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diately after lobectomy or pneumonectomy in man, may tend to precipitate pulmonary edema. On the other hand, inadequate replacement of blood lost may lead to surgical shock. Changes in the pulse rate and blood pressure are not reliable signs of blood loss, especially in the older, poor-risk patient. It is obviously desirable to maintain a normal circulating blood volume at all times during a major operation. This can be accomplished only by transfusing blood during the surgical procedure at the same rate that it is lost in the operative wound.

Coller, Crook, and Iob,[3] Stewart and Rourke,[11] and McAllister[12] have shown that postoperative changes in the hematocrit, hemoglobin, and plasma protein are not necessarily related to changes in the blood and plasma volumes and consequently cannot be used to determine blood loss. The amount of blood and fluid lost must, of necessity, be based on direct measurement.

Sponge Weight Method.—Dry sponge technique[7] was employed during the entire surgical procedure. A weighing scale of 0.1 Gm. sensitivity was used. All sponges and aspiration bottles were weighed immediately before operation. They were weighed again, immediately after use, to minimize error resulting from evaporation. The blood loss was calculated from gain in weight of sponges and aspiration bottles. This value was then converted to volume of blood in cubic centimeters by multiplying by 1.055 which was arbitrarily taken to be the average specific gravity of blood.

Dye Method for Determining Blood Volume.—The T-1824 method of Gibson and Evans,[13] adapted for use with the Evelyn colorimeter by Gibson and Evelyn,[14] was used to determine plasma volumes. Ampules* containing a sterile aqueous solution of T-1824 in 0.5 per cent concentration were used. Each batch of dye was standardized before use. Blood volume determinations were performed with the patient in the recumbent position. Postoperative determinations were made within forty-five minutes after conclusion of the operation. The quantity of dye used varied with the size of an individual. Large quantities of dye may produce objectionable discoloration of the skin, especially in patients having small plasma volumes. Little, if any, discoloration of the skin results from a dose of 0.25 mg. per kilogram of body weight.

Syringes and needles used for injection of the dye were volumetrically calibrated for delivery by determining the weight of distilled water delivered. Syringes were filled with distilled water to the point where marks on both the plunger and barrel coincided. The water was then expelled through a dry needle into a weighing bottle. Recalibrations were performed at intervals to assure continued accuracy. Using calibrated syringes, the difference between repeated determinations, done within a twenty-four hour period, in twenty-five instances lay between 0.4 and 7.0 per cent. The mean experimental difference in repeat determinations in patients was 4.0 per cent. The standard error of estimation was ±176 c.c.[15]

The dye was injected within a period of five seconds into a large vein of the forearm by means of the calibrated syringe. The syringe was not flushed

*Obtained from William R. Warner & Company, New York, N. Y.

with blood. The site of puncture was firmly compressed after withdrawal of the needle in order to prevent extravasation of the dye. The first blood sample was obtained from the vein of the opposite arm seven and one-half minutes after the beginning of the dye injection. Four or five additional blood samples were obtained at two and one-half minute intervals. The blood was permitted to clot and clear serum obtained by centrifugation at 2,000 R.P.M. for fifteen minutes. Obviously hemolyzed serum samples were discarded. The optical density of the dye was measured with the Evelyn photomicrocolorimeter at a wave length of 620 mμ. Any slight hemolysis was detected by measurement at 540 mμ,[13] and the light transmission at 620 corrected by this value. The correction was usually insignificant. The corrected values of optical density of T-1824 were then plotted against time and the optical density at zero time found by extrapolation. All plasma volumes were calculated from the extrapolated optical density. Blood volumes were calculated from the plasma volumes and the hematocrit. Plasma protein concentrations were obtained by the copper sulfate method.[16]

Cruickshank[17] has shown a marked difference in the slope of the excretion curve of T-1824 in repeated determinations. The mixing time of the dye is also prolonged in shock.[18] Because of the possibility of changes in the mixing time and the excretion rate of the dye, in the immediate postoperative period, we have attempted to minimize the error of the method by employing the extrapolated values of the optical density instead of using that measured in a single ten minute sample. Furthermore, we have found that the plasma volume calculated from the optical density of the dye in a single ten minute sample may be between 0.5 and 3.0 per cent higher than that calculated from the optical density of the dye extrapolated to zero time. Blood volume measurements using isotopic iron have been consistently lower than those obtained with the dye method.[19]

Blood lost during the operation was computed by subtracting the postoperative blood volume from the preoperative blood volume and adding the amount of blood transfused during operation. In most instances the exact amount of blood transfused during operation was determined by weighing the transfusion bottles before and after use. The amount of 5 per cent glucose in water given during operation was also measured by weighing the containers before and after use.

Sodium Thiocyanate Method for Determining Extracellular Fluid.—The fluid available for the dilution of sodium thiocyanate, hereafter referred to as the extracellular fluid, was determined both preoperatively and postoperatively as ferric thiocyanate according to the method of Crandall and Anderson.[20] Syringes used for the injection of sodium thiocyanate were volumetrically calibrated to the tip by determining the weight of distilled water contained. An average of 15 mg. per kilogram of sterile 5 per cent sodium thiocyanate solution* was injected intravenously approximately thirty minutes prior to the injection of T-1824. The syringe was then flushed three times with blood to insure

*Obtained from William H. Rorer, Inc., Philadelphia, Pa.

complete delivery. Blood samples for thiocyanate determination were obtained thirty minutes after injection, at which time diffusion equilibrium is usually attained.[11, 20, 21] The dye T-1824 was then injected through the same needle immediately after withdrawal of the thirty minute blood sample for thiocyanate determination. Additional thiocyanate determinations were made from blood samples withdrawn for plasma volume determinations. The dye is completely precipitated during the preparation of the protein-free filtrate and consequently does not interfere with the measurement of thiocyanate concentration.[22] The thiocyanate concentration in each sample, measured as ferric thiocyanate with the Klett-Summerson colorimeter, was then plotted against time. Calculations of extracellular fluid were based on the thiocyanate concentration at the point where excretion assumes a constant value. In many instances the concentration continued to decline at a steady rate. The calculation of extracellular fluid in these instances was based on the concentration of the thirty minute sample.

The mean experimental difference between repeat determinations within seventy-two hours in six patients was 3.3 per cent with a minimum and maximum difference of 1.0 and 5.8 per cent. The standard error of estimation was ±337 c.c.

OBSERVATIONS

Plasma volume was determined by using the blue dye T-1824 both preoperatively and postoperatively in a series of fifty-seven patients subjected to major thoracic operations. Blood volume was calculated from the plasma volume and the hematocrit. The extracellular fluid volume was measured with sodium thiocyanate both preoperatively and postoperatively in thirty-three patients in this series. Blood loss during operation was measured by the sponge weight method in twenty-seven instances.

Comparison Between the Sponge Weight Method and Dye Method for Determining Blood Loss.—Both methods for measuring blood loss were used in twenty-seven major thoracic operations (Fig. 1). In twenty-one instances the blood loss by the dye method was greater than the loss estimated by the sponge weight method. In general, the difference between the two methods was not marked. The greatest differences were 592 and 434 c.c. in Cases 19 and 14, respectively.

Thoracoplasty.—Postoperative blood volume changes were studied in ten patients subjected to first stage thoracoplasty (Table I). The extracellular

TABLE I. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING FIRST STAGE THORACOPLASTY (TEN CASES)

	BLOOD LOST* (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID LOSS 5 CASES (C.C.)
Minimum	406	340	252
Maximum	1885	575	2840
Average	734	475	1352

*The figures for "blood lost" were derived from blood volume determinations in this and in subsequent tables.

fluid volume was studied in five of these patients. Blood loss during operation was gravimetrically measured in four instances. The average operative time was two hours, sixteen minutes. Continuous spinal anesthesia was used in all cases.

The maximum postoperative blood volume deficiency was 1385 c.c. or 23.5 per cent of the preoperative blood volume, though clinical evidence of shock did not occur. A postoperative increase in hematocrit values was observed when blood loss had been adequately replaced. A decrease was observed when blood loss had been inadequately replaced with the exception of one patient. All patients were deficient in extracellular fluid volume postoperatively.

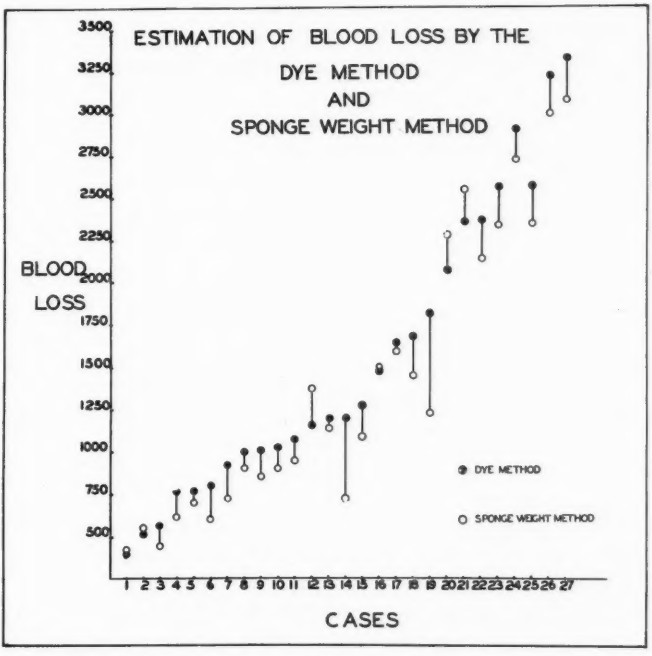

Fig. 1.—Ordinates represent blood loss in cubic centimeters. The twenty-seven cases are arranged in the order of increasing blood loss.

Thoracotomy.—Postoperative blood volume changes were studied in eleven patients subjected to thoracotomy (Table II). Six patients had inoperable carcinoma of the lung, three had inoperable carcinoma of the esophagus, and two had extrapulmonary tumors removed. The extracellular fluid volume was studied in seven of these patients. Blood loss during operation was measured by the sponge weight method in seven instances. The average operative time was two hours. Endotracheal ether anesthesia was used in all instances.

The maximum postoperative blood volume deficiency was 504 c.c., or 10.3 per cent of the preoperative blood volume. Clinical evidence of shock did not

TABLE II. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING THORACOTOMY (ELEVEN CASES)

	BLOOD LOST (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID	
			GAIN 6 CASES (C.C.)	LOSS 1 CASE (C.C.)
Minimum	364	500	115	122
Maximum	1679	1980	1323	
Average	1074	977	+559	

develop in any of these patients. A postoperative increase in the hematocrit value was noted when the blood lost was adequately or more than adequately replaced, although no quantitative relationship existed. A decrease in the hematocrit value was observed when the blood lost was inadequately replaced, except in two instances. Postoperatively, no patients showed a significant loss in extracellular fluid volume.

Partial Lung Resection.—Postoperative blood volume changes were studied in thirteen patients subjected to lobectomy for bronchiectasis. The extracellular fluid volume was studied in nine of these patients. Blood loss during operation was measured by the sponge weight method in seven instances. The average operative period was three hours, fifty-one minutes. Endotracheal ether anesthesia was used in all cases (Table III).

TABLE III. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING LOBECTOMY (THIRTEEN CASES)

	BLOOD LOST (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID	
			GAIN 2 CASES (C.C.)	LOSS 7 CASES (C.C.)
Minimum	700	1066	107	499
Maximum	2919	2723	125	3860
Average	1778	1771	−1110	

The maximum postoperative blood volume deficiency was 857 c.c., or 22 per cent of the preoperative blood volume. This patient showed clinical evidence of shock. A postoperative increase in the hematocrit value was observed in patients with adequate and excessive blood replacement. No quantitative relationship between the hematocrit and degree of over-replacement existed. Postoperatively, a decrease in the hematocrit was observed in cases with inadequate replacement except in two instances. There was a significant decrease in the extracellular fluid volume in five of the nine patients studied.

Esophagectomy.—Postoperative blood volume changes were studied in seven patients subjected to esophagectomy for lesions involving the thoracic esophagus. In six instances esophagectomy was performed for carcinoma and once for esophageal stricture. The extracellular fluid volume was studied in three of these patients. The average operative time was five hours, twenty-nine minutes. Endotracheal ether anesthesia was used in all cases (Table V).

TABLE IV. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING PNEUMONECTOMY (SIXTEEN CASES)

	BLOOD LOST (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID	
			GAIN 1 CASE (C.C.)	LOSS 7 CASES (C.C.)
Minimum	684	850	522	408
Maximum	3597	3658		2361
Average	1915	1954	−1158	

TABLE V. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING ESOPHAGECTOMY (SEVEN CASES)

	BLOOD LOST (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID	
			GAIN 2 CASES (C.C.)	LOSS 1 CASE (C.C.)
Minimum	1284	1000	38	1888
Maximum	2570	3000	1278	
Average	1876	2228		

The maximum postoperative increase in blood volume was 839 c.c. This represents an increase of 17.8 per cent of the preoperative blood volume. This patient did not develop any postoperative respiratory or circulatory complications. Postoperative increase in the hematocrit was observed in all cases of adequate and over-replacement. A decrease in the hematocrit was observed in the one patient in whom blood loss was inadequately replaced. One patient showed a significant deficiency in extracellular fluid volume postoperatively. There was a postoperative gain in extracellular fluid in the other two patients. In both these patients there was a more than adequate replacement of blood and fluid.

Total Lung Resection.—Postoperative blood volume changes were studied in sixteen patients subjected to pneumonectomy. Pneumonectomy was performed in thirteen of these patients for carcinoma, and in three for bronchiectasis. Changes in the state of hydration were studied in eight of these patients. Blood loss during operation was gravimetrically measured in six instances. The average operative time was three hours, fifty-seven minutes. Endotracheal ether anesthesia was used in all cases (Table IV).

The maximum postoperative blood volume deficiency was 878 c.c. This represents a deficiency of 16.3 per cent of the preoperative blood volume. Clinical evidence of shock was not observed in any patient. In one instance, the postoperative blood volume was 732 c.c., or 17.4 per cent greater than the preoperative value. This patient did not develop any postoperative respiratory or circulatory complications. Postoperatively, the change in the hematocrit values could not be correlated with changes in the blood volume.

In eight determinations of the extracellular fluid volume, only one patient showed a gain of 522 c.c. In this instance there was over-replacement of both

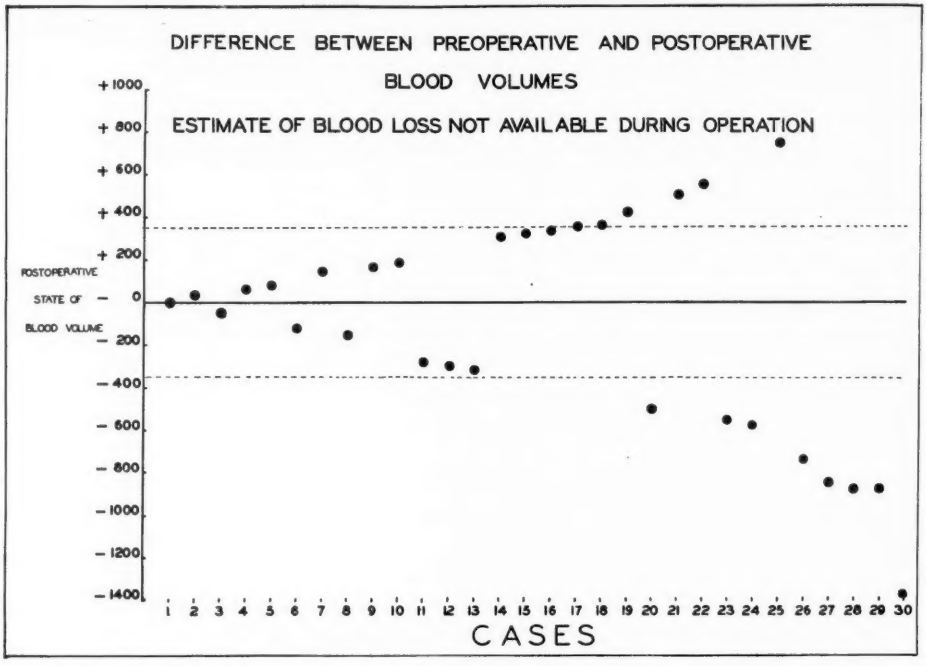

Fig. 2.—Ordinates represent increase, or decrease, in postoperative blood volume in cubic centimeters. Sponge weight method was not used.

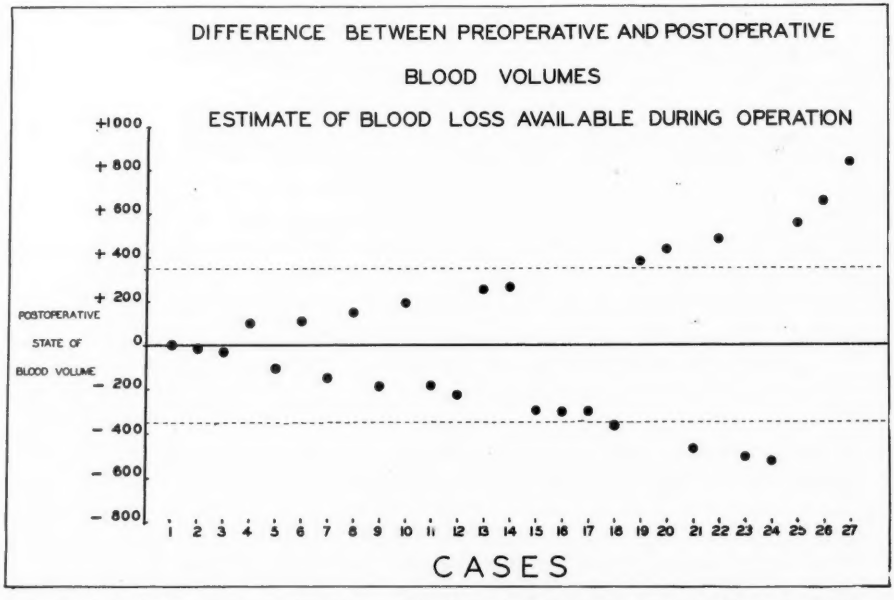

Fig. 3.—Ordinates represent increase, or decrease, in postoperative blood volume in cubic centimeters. Sponge weight method was used.

blood and fluid during a short operation. There were significant decreases in the extracellular fluid in the other seven patients.

Blood Replacement Controlled by Gravimetric Estimate of Blood Loss.— In thirty of the fifty-seven patients studied, the sponge weight method of estimating blood loss was not used. In this group the blood loss was significantly over-replaced in six patients and significantly under-replaced in eight patients (Fig. 2). The maximum postoperative blood volume deficiency in this group was 1,385 c.c.

In the remaining twenty-seven patients an estimate of blood loss by the sponge weight method was available *during* the operation. In this group the blood loss was significantly over-replaced in six patients and significantly under-replaced in four patients (Fig. 3). The maximum postoperative blood volume deficiency in this group was 540 c.c. It would appear that when an estimate of the blood loss is available during the operation, a normal blood volume can be more easily maintained and serious under-replacement of blood avoided.

DISCUSSION

The average values for blood loss during major thoracic operations presented in this paper are in general agreement with those reported by others. The blood loss computed by the dye method is believed to be more indicative of the actual blood loss, since small quantities of blood may escape detection by the sponge weight method. The dye method generally gave higher values for blood loss than the sponge weight method. This may be related to the blood and plasma loss into the wound and pleural cavity postoperatively and prior to the blood volume determination. Thomas, Adams, and Thornton[23] have shown that the hemoglobin concentration and red blood cell count decrease steadily during the postoperative period, reaching the lowest level from the third to the eighth day.

Coller and Maddock[24] investigated dehydration during surgical operations by weighing the patient preoperatively and postoperatively. Water loss varied between 97 and 705 Gm. during uncomplicated procedures. When one considers the large surface area exposed in an open pleural cavity, losses of large quantities of water by evaporation are to be expected. The large surface exposed during thoracoplasty, especially in first stage procedures, may account for the fluid loss in these patients. Shorter operative procedures such as exploratory thoracotomy are not accompanied by large fluid loss. In fact, most of these patients showed a gain in extracellular fluid postoperatively. A postoperative increase in the extracellular fluid has previously been observed by Stewart and Rourke[11] which they attributed to ether anesthesia. Cope and Moore[25] have recently reported gains in extracellular fluid as great as 50 per cent in seriously burned patients. McAllister[12] noted an average decrease of 11 per cent in the plasma volume of experimental animals after ether anesthesia.

SUMMARY

1. Blood volume was measured by the dye method before, and immediately following, fifty-seven major thoracic operations.

2. In twenty-seven of these fifty-seven patients the blood lost at operation was estimated by weighing gauze sponges before and after use in the operative field.

3. The blood lost during operation was more accurately replaced by transfusion when the sponge weight method was used.

4. Significant losses of extracellular fluid usually occurred during long operations.

CONCLUSION

In major thoracic operations it is important to measure blood loss by observing the increase in weight of the gauze sponges used. At present this is the only method which gives a continuous record of the blood lost during the course of an operation, and hence, permits simultaneous accurate replacement by blood transfusions.

The technical assistance of Mr. Franz Goldstein and Miss Theresa D'Urso is gratefully acknowledged.

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DISCUSSION

DR. GIBBON.—We began this work one year ago because in major intrathoracic operations we found that we were unable to estimate the amount of blood which had been lost, and thus the amount which should be replaced, by observing the pulse rate and the blood pressure. In a number of patients in whom we had inadequately replaced blood, the pulse rate was quite slow and the blood pressure did not fall until just before a rather precipitous drop. We think that great credit should go to Wangensteen for having suggested the simple method of weighing gauze sponges before and after their use and estimating blood loss by that method. So far as we are aware, there is, at present, no other simple method of determining during the course of an operation how much blood has been lost.

We use this method in all our major thoracic procedures. However, there are two other conditions where it may be quite valuable. One is when there has been quite a large sudden blood loss during an operation and the exact quantity to be replaced is uncertain. The other is—we have had no experience with it but we think it might be of use in that condition—in the second stage of thoracolumbar sympathectomies. The blood pressure after an initial fall following the first stage has returned to high levels. In the second stage there may be considerable bleeding, and after removal of the sympathetic chain there may be a precipitous drop in pressure. The question is whether the drop is due to the sympathectomy or to the blood loss. This can be determined easily by weighing the sponges used. The method then may be of considerable help to neurosurgeons in these situations.

BILOBECTOMY—SURGICAL AND ANATOMIC CONSIDERATIONS IN RESECTION OF RIGHT MIDDLE AND LOWER LOBES THROUGH THE INTERMEDIATE BRONCHUS

G. E. LINDSKOG, M.D., AND (BY INVITATION) A. A. LIEBOW, M.D., AND M. R. HALES, M.D.
NEW HAVEN, CONN.

THE multisegmental nature of bronchiectasis is coming to be increasingly recognized with accumulating clinical experience and with the more widespread use of complete bilateral bronchography before the institution of surgical treatment. Among 140 cases of bronchiectasis so studied at New Haven Hospital on the thoracic surgical service[1] only 52 appeared to be confined to a single lobe or unilobar segments. The right lower and middle lobes were involved simultaneously in 19 cases, and of these there was no other demonstrable ipsolateral or contralateral involvement in 8. Stated another way, of 58 cases where right lower lobe bronchiectasis was present, the middle lobe was also similarly diseased in 19, or 33 per cent.

It is of practical importance, therefore, to consider an operative technique by which these two lobes can be removed as a single surgical unit through the common intermediate bronchus. The method usually followed is to carry out seriatim lobectomies through the respective lobar bronchi. This technique has the disadvantage of leaving a long intermediate bronchus with two end stumps, and of requiring two sets of bronchial sutures, with possibly increased chances of leakage. Moreover, the longer double stump may be more difficult to cover securely with pleura during the final steps of the closure.

The excellent anatomic studies of Boyden[2] on the bronchovascular arrangements in the human lung as well as the results of certain bronchovascular injection studies carried out in this clinic with a suitable vinylite plastic medium[3] (Fig. 1) have indicated the feasibility of a simultaneous right middle and lower bilobectomy to replace individual lobectomy performed seriatim. In presenting this development, priority is not claimed since the possibility of this procedure has already occurred to other surgeons on the basis of available anatomic knowledge.[4] However, the surgical and anatomic details of such a procedure are still wanting in the literature.

SURGICAL TECHNIQUE

Under intratracheal cyclopropane, oxygen, and ether anesthesia the patient is placed in the left lateral decubitus position and the seventh right rib is resected. Adhesions are cleared from the lateral, posterior, and lateral diaphragmatic aspects of the two lobes to be removed. If the oblique fissure between the

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subapical segment of the upper lobe and the dorsal (apical) segment of the lower lobe is incomplete, this is developed by sharp and blunt dissection to expose the arterial branch to the apical segment (Boyden's A 6) (Fig. 2). This vessel is doubly ligated with silk and divided. By this maneuver some mobility of the main arterial trunk is gained, and lateral access to its posterior surface

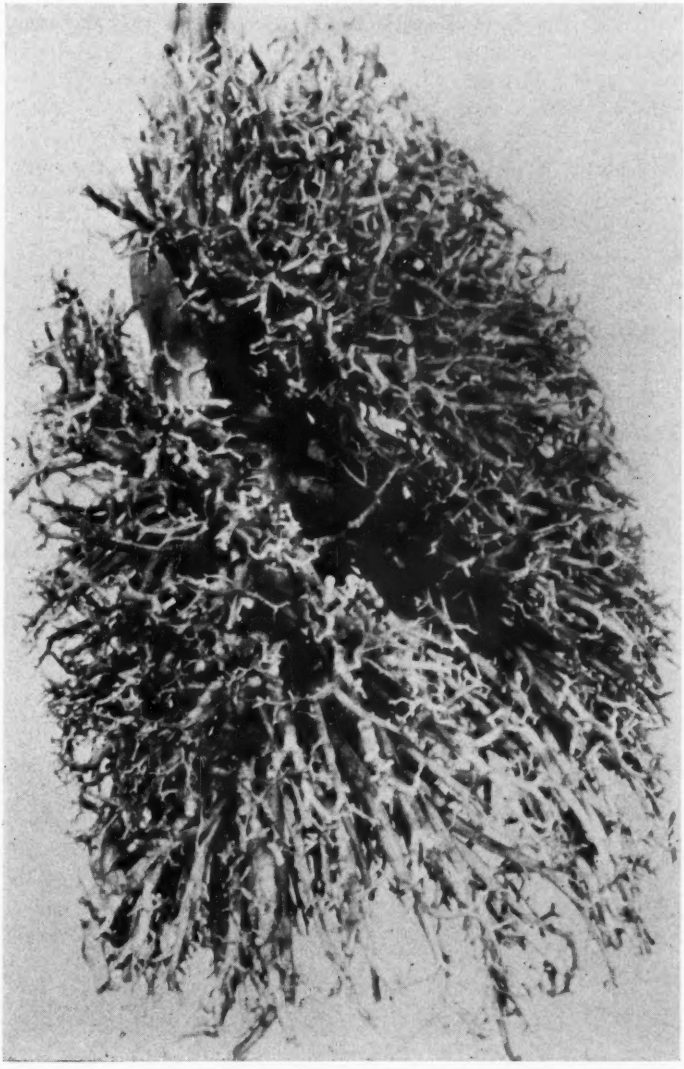

Fig. 1.—An untrimmed vinylite cast of the bronchi and pulmonary vascular tree. Right lung of a male adult, Case 7700.

on the bronchus is obtained. The arterial branch to the middle lobe lateral segment (Boyden's A 4) or the middle lobe common trunk (see below) is now sought anteriomedially, and is similarly ligated and divided. For isolation of all these vessels a blunt curved ligature carrier or a Mixter clamp is employed. It is

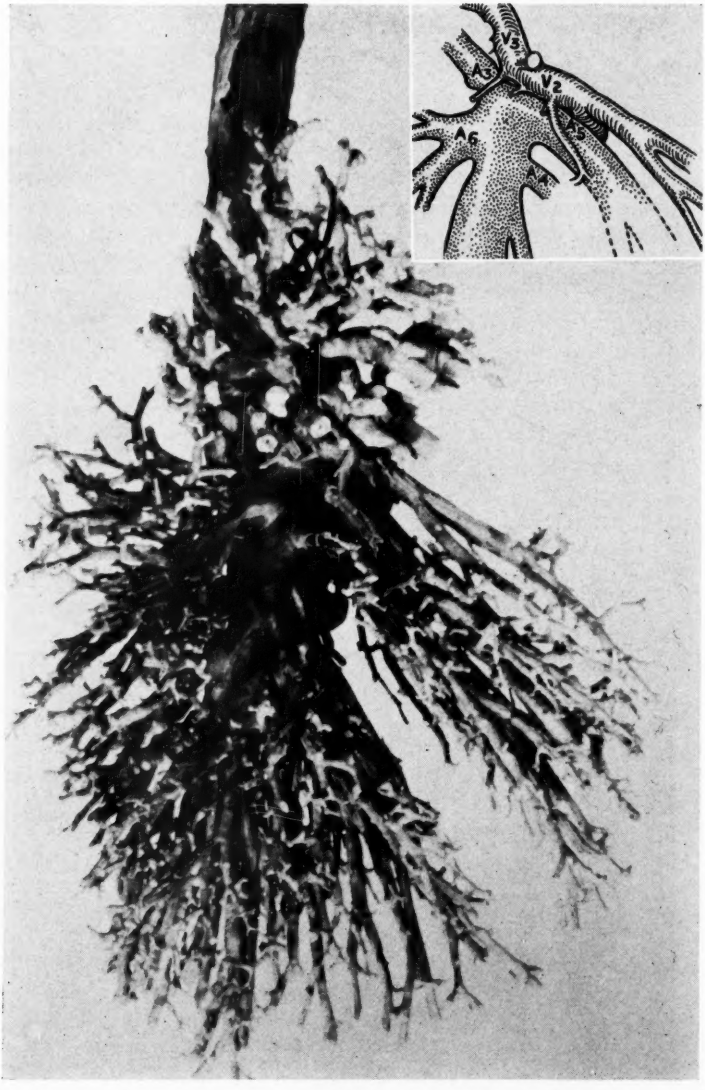

Fig. 2.—Partly trimmed cast from same specimen of Fig. 1 showing the arterial distribution, with double arteries (A4, A5) to middle lobe. Apical artery (A6) lies at an intermediate level. This branch is ligated first in the surgical approach. Note proximity of subapical artery (A3) and absence of a true intermediate artery in this case.

now possible in most cases to isolate the main arterial trunk above these two branches and below the origin of the upper lobe branches, and to divide the trunk after ligation and transfixion. (See discussion on variations.)

Next the posterior pleural reflexion from the lower lobe to the pulmonary ligament is opened. The lower pulmonary vein is isolated by dissection with a blunt clamp holding a cotton pledget moistened in 1 per cent Novocain solution. This vessel is ligated, transfixed, and divided (Figs. 3 and 4).

Attention is next directed to the fissure between pectoral segment of upper and middle lobes. Unfortunately this fissure is incomplete to some degree in over 50 per cent of individuals and must be developed. As the hilus is approached, the medial artery to the middle lobe is encountered (Boyden's A 5). The corresponding veins will be found to enter the superior (upper lobe) vein or independently into the atrium. Care should be taken in ligation and transfixion *not* to include the upper lobe venous radicles.

The intermediate bronchus is now cleared by blunt dissection, elevating the divided major arterial trunk out of the way by gentle traction forward and upward. Guide sutures are placed in the bronchial wall medially and laterally and the transection of the bronchus begun. *Without clamping proximally,* a small incision is made on the edge of the bronchus, and an interrupted silk suture, size 000, is used to approximate the cut edge. The incision is deepened and another suture or two placed. Suction is used at the stump continually with this technique to prevent aspiration of blood into the lumen. The division and suture are completed. Finally the mediastinal aspect of the middle lobe is freed from the pericardium and propericardial fat, the diaphragmatic dissection completed, and the anterior layer of the pulmonary ligament divided if this has not already been accomplished. The two lobes can now be lifted out by the common bronchial stem without any dissection in the oblique fissure between them (Fig. 11).

Repair of the mediastinal pleural defect is readily accomplished, care being taken not to interfere with the phrenic nerve in its neighboring course. Any raw surface on the pectoral division of the upper lobe is allowed to remain without infolding after detailed hemostasis.

The pleural cavity is lavaged with saline solution, all fluid aspirated, and 100,000 units of penicillin introduced. The chest wall is then closed in layers using interrupted silk technique. During the closure, the anesthetist controls reinflation of the upper lobe and this is assisted by catheter aspiration of the pleural cavity as the final layers are completed. Neither pleural cavity nor wound needs to be drained for the usual case. Postoperatively penicillin is given systemically until the temperature has been normal for forty-eight hours. Pleural aspirations are performed as indicated.

ANATOMIC VARIATIONS

The operation described here deals with the most common anatomic disposition of the vascular branches to the middle and lower lobe. Certain important variations occur with sufficient frequency to necessitate a systematic study. For this purpose twenty-five autopsy specimens of right lungs were prepared

by colored vinylite plastic injections of the bronchial and vascular trees, according to a technique previously developed in this laboratory.[3] The prepared specimens were dissected sufficiently to permit study and measurement. The results are recorded in Table I, and may be summarized as shown there.

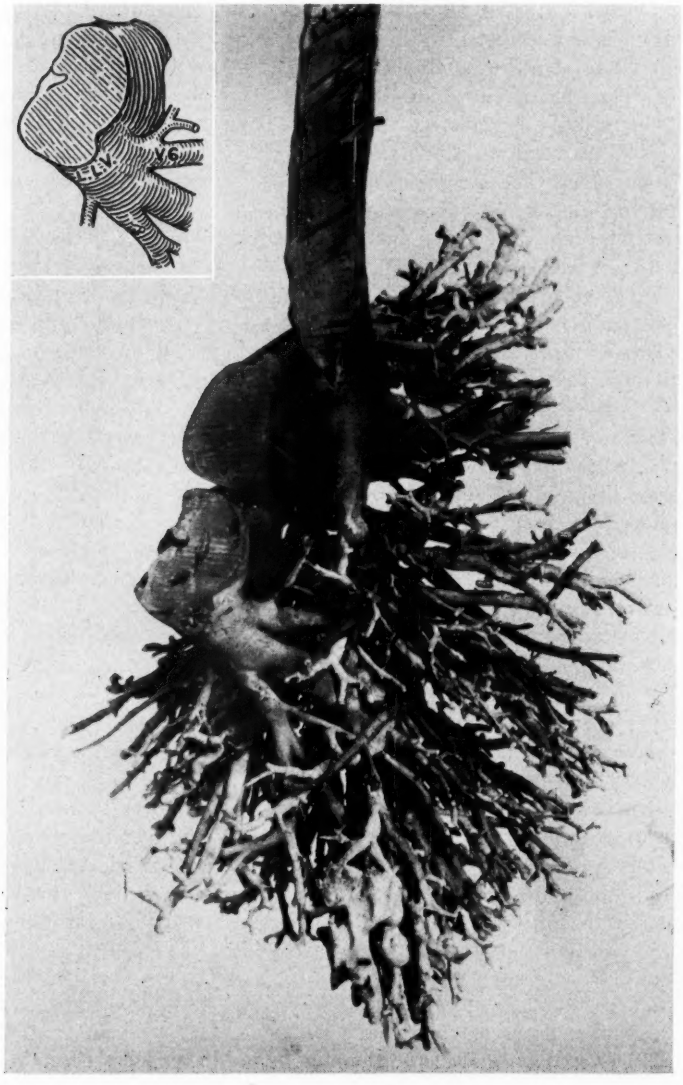

Fig. 3.—Posterior aspect of same cast, showing inferior vein and its radicles, in position for surgical ligation.

TABLE I

SPECIMEN NO.	LENGTH OF INTERM. ART. (IN MM.)	R.M.L. ARTERIES: SEPARATE OR COMMON TRUNK	R.M.L. ARTERIES: DIST. SEP. OR LT. OF COM. TR. (IN MM.)	R.M.L. VEINS: SEPARATE OR COMMON TRUNK	R.M.L. VEINS: DRAINAGE	CROSSED INTERLOBAR VENOUS DRAINAGE	REMARKS
7518	3	Separate	10	Common trunk	Sup. vein	No	
7541	12	Separate	5	Separate	Sup. vein	Yes*	*Small R.M.L. vein drains into pectoral vein
7545	None	Separate	10	Common trunk	Atrium	Yes*	*Apical vein of R.L.L. drains into subapical vein of R.U.L.; artery to axillary portion of subapical segment of R.U.L. arises from apical artery of R.L.L.
7563	5	Common trunk	9	Common trunk	Sup. vein	?*	*Injection too coarse
7567	None	Common trunk	5	Common trunk	Sup. vein	?	*Subapical artery of R.U.L. and apical artery of R.L.L. arise from common trunk
7602	10	Separate	5	Separate	Sup. vein	No	
7655	9	Common trunk	6	Separate	Sup. vein	?*	*Injection too coarse
7685	9	Separate	8	Separate	Sup. vein Atrium	No	
7689	11	Common trunk	12	Common trunk	Atrium	Yes*	*Vein of medial segment of R.M.L. drains into pectoral vein of R.U.L.
7693	18	Separate	6	Separate	Sup. vein	No	
7695	13	Separate	12	Common trunk	Sup. vein	No	
7700	None	Separate	10	Common trunk	Sup. vein	Yes*	*Small lateral vein of R.M.L. drains into pectoral vein of R.U.L.
7702	12	Common trunk	22	Common trunk	Atrium	Yes*	*A large vein of R.M.L. drains into pectoral vein of R.U.L.
7715	10	Common trunk	11	Common trunk	Sup. vein	No	
7726	7	Common trunk	2	Separate	Sup. vein	Yes*	*Small superficial vein of R.M.L. drains into pectoral vein of R.U.L.
7732	13	Separate	5	Separate	Sup. vein	No	
7746	7	Common trunk	14	Separate	Sup. vein	Yes*	*Vein of anterior portion of pectoral segment of R.U.L. drains into superior vein of R.M.L.
7750	6	Common trunk	8	Common trunk	Atrium	Yes*	*Vein of apical segment of R.L.L. drains into subapical vein of R.U.L. which in turn drains into pectoral vein of R.U.L.; also a vein of R.M.L. drains into pectoral vein of R.U.L.
7752	None	Common trunk	16	Common trunk	Sup. vein	Yes*	*A vein of R.M.L. drains anteriorly into pectoral vein of R.U.L.
7755	4	Separate	6	Common trunk	Sup. vein	No	
7758	9	Common trunk	18	Common trunk	Sup. vein	No	
7760	None	Common trunk	18	Common trunk	Sup. vein	No	*Subapical artery of R.U.L. arises from apical artery of R.L.L.
7762	5	Common trunk	12	Common trunk	Sup. vein	No	
7765	None	Separate	9	Separate	Sup. vein	No	
7773	3	Common trunk	13	Common trunk	Atrium	Yes*	*One small vein of R.M.L. crosses superficially in region of obliterated R.U.L.-R.M.L. fissure to drain into pectoral vein of R.U.L.

Variations in the Intermediate Artery.—The intermediate artery is defined as that segment of the right pulmonary arterial trunk between the lowest branch to the upper lobe (A 3) and the highest branch to the middle lobe or the common middle lobe trunk (Fig. 5). In most cases (19 of 25, or 76 per cent) a definite intermediate artery was present, with a range of 3 to 18 mm. in length, averaging 8.2 mm. In the remaining 6 specimens the artery to the subapical segment

Fig. 4.—Anteromedial view of same cast, showing merging of lateral and medial segmental middle lobe veins into a common trunk which enters the extralobar portion of the superior vein. In this case the fissure between upper and middle lobe was incomplete anteriorly. A large branch of pectoral vein (V2) crosses the fissure and requires ligation.

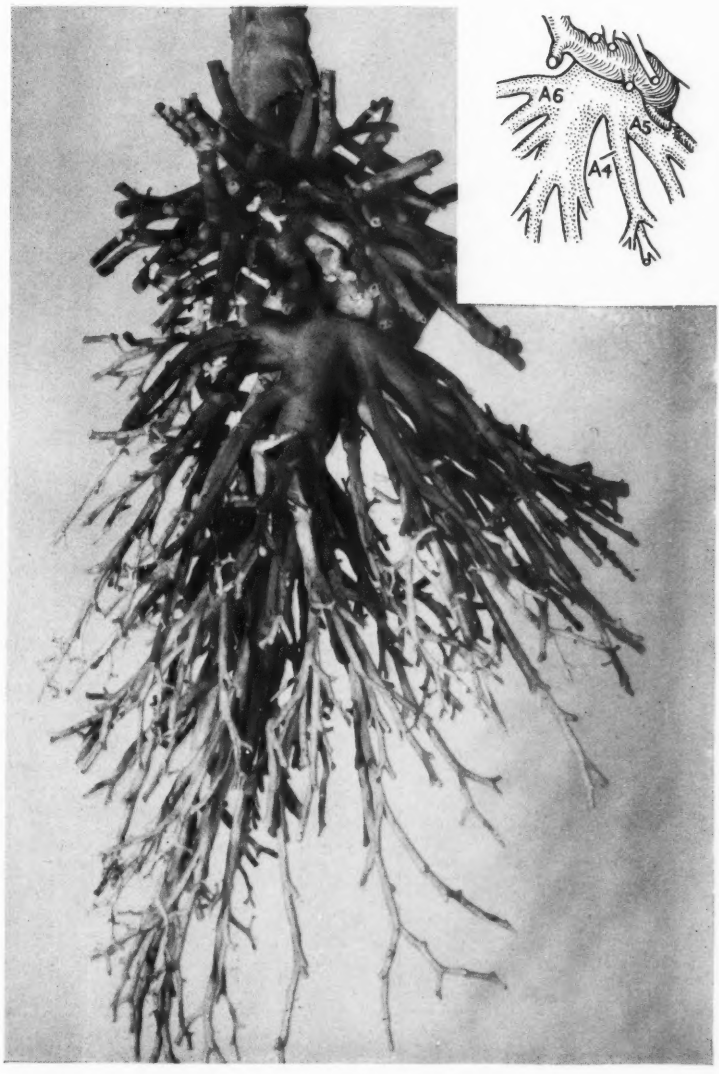

Fig. 5.—Another trimmed bronchovascular cast (7655), showing example of common middle lobe arterial trunk, and well-developed intermediate artery trunk measuring 9 mm. in length. Pulmonary artery red, vein green, bronchus white.

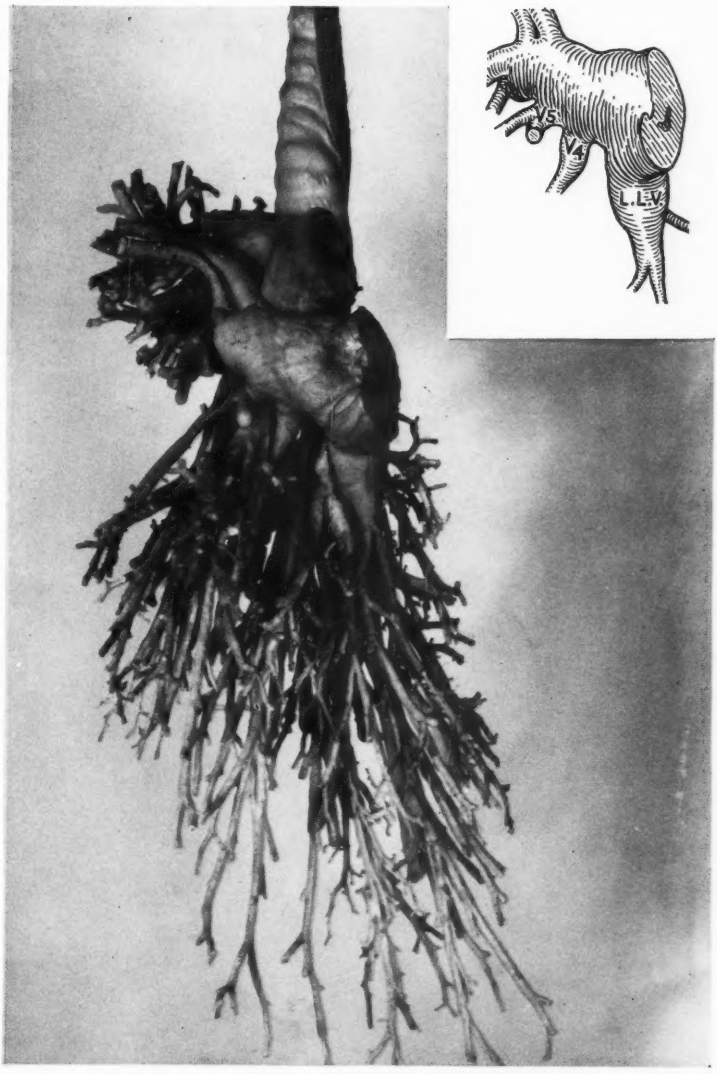

Fig. 7.—Anteromedial view of Case 7655 (same as Fig. 5) showing separate segmental vein of middle lobe (V4 and V5) entering the extralobar portion of superior vein. In this case there was a common *arterial* trunk.

of the right upper lobe (A 3) arose at the same level as the first branch to the middle lobe. Obviously, in this group of cases, surgical ligation would be accomplished through the individual lobar branches rather than the trunk.

In three instances where the intermediate arterial stem was wanting, the artery to the subapical (posterior) segment of the upper lobe or its axillary

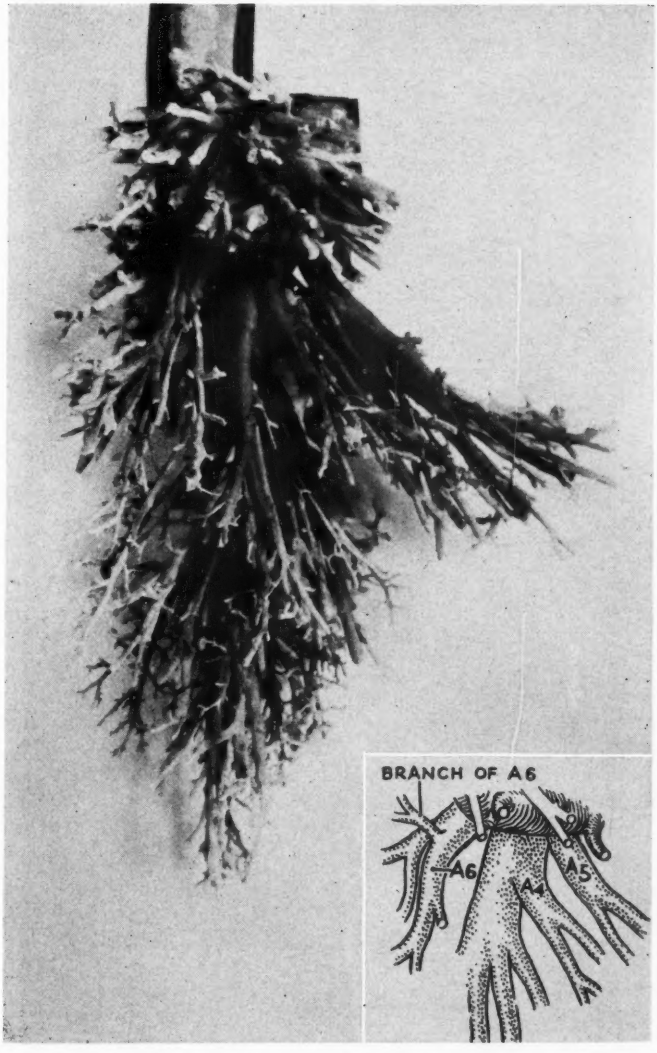

Fig. 6.—Trimmed bronchovascular cast (Case 7545) showing ascending branch from apical segment artery (A6) to subapical segment of the adjacent upper lobe. In this case the posterior portion of the interlobar fissure was incomplete; a good example of separated middle lobe arteries. Compare with Fig. 2.

portion took origin from the artery to the apical segment of the lower lobe (A 6) (Fig. 6). The existence of this variation should be suspected when the fissure between these two segments is incomplete or wanting upon examination of the lung at operation.

Variations in the Middle Lobe Arteries.—The lateral (A 4) and medial (A 5) segmental arteries of the middle lobe arose separately in 11 of 25, or 44 per cent, and as a common trunk in 14, or 56 per cent. Whether arising separately or in common, the middle lobe arterial supply was usually located

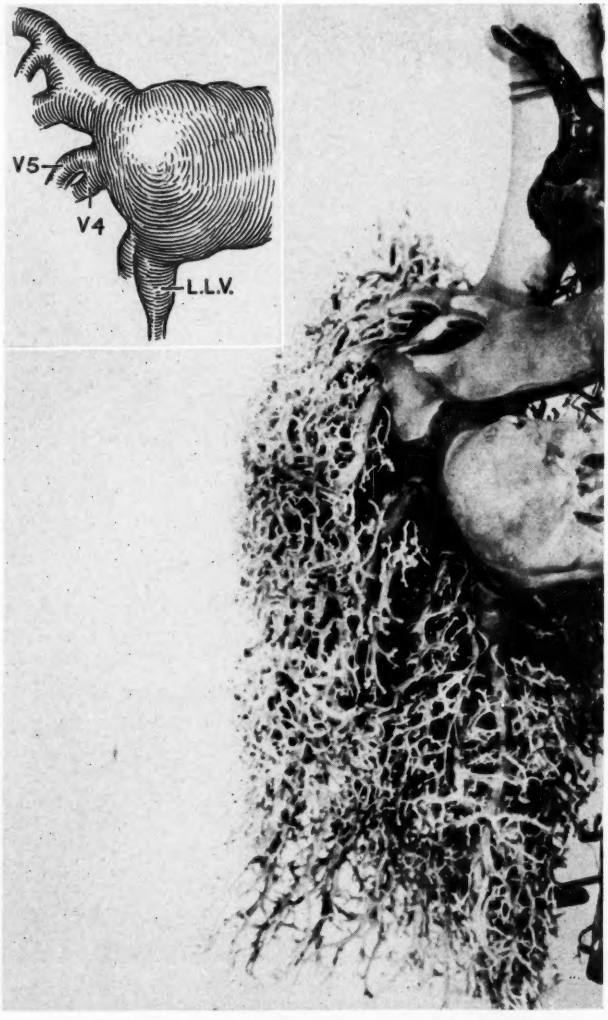

Fig. 8.—Common middle lobe venous trunk emptying into left atrium, Case 7773.

slightly higher than the origin of the artery to the apical (dorsal or superior) segment of the lower lobe (A 6).

When the two segmental vessels to the middle lobe arose from a common trunk, its length varied from 2 to 22 mm. with an average of 11.8 mm. before division into medial and lateral branches.

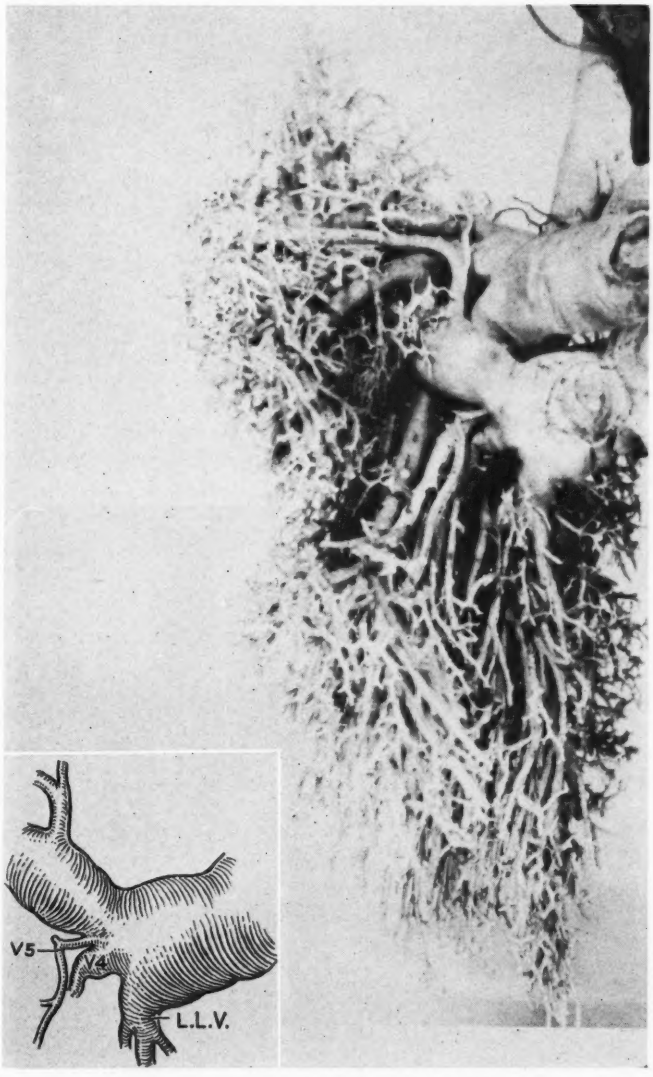

Fig. 9.—Cast of Case 7685 in which one middle lobe vein (V5) drains to upper lobe vein and the other (V4) into atrium.

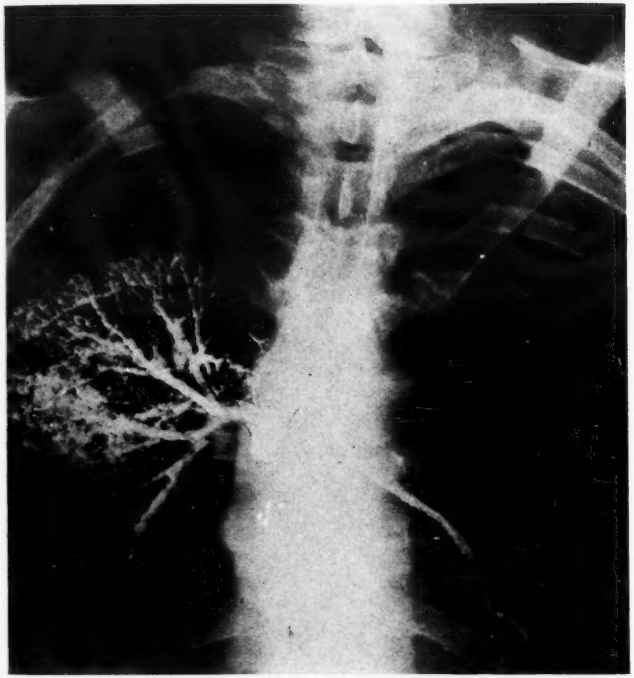

Fig. 10.

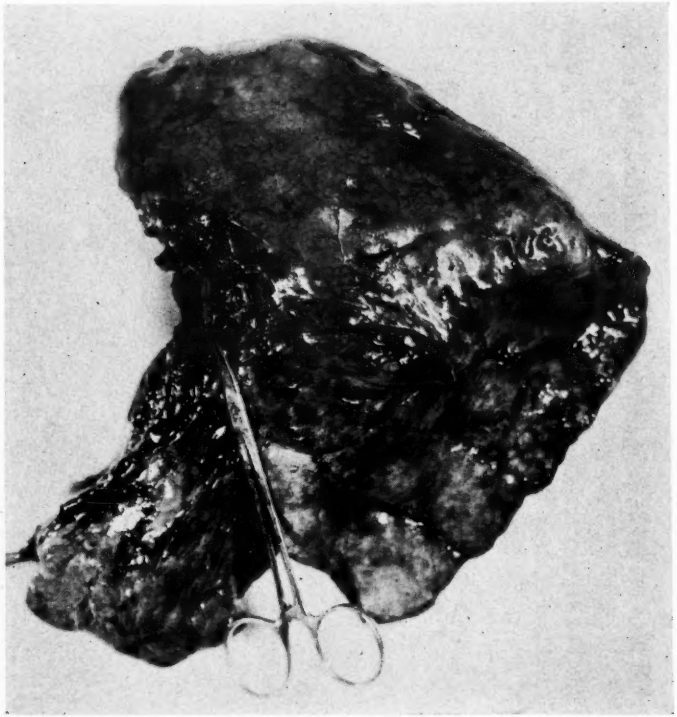

Fig. 11.

Fig. 10.—Bronchogram of postoperative chest showing stump of intermediate bronchus outlined by lipiodol.

Fig. 11.—Photograph of excised bilobectomy specimen, showing middle and lower lobes still attached, and bifurcation of intermediate bronchus visualized.

When the two segmental vessels to the middle lobe (A 4 and A 5) arose independently from the intermediate trunk, the distance between their orifices varied from 5 to 14 mm. with an average of 8.3 mm.

Variations in the Middle Lobe Veins.—In the majority of instances, 64 per cent, the veins from the two segments became confluent; in 36 per cent they were separate as they entered the extralobar superior (upper lobe) vein or the atrium (Figs. 7 and 8). Drainage was to the extralobar portion of the upper lobe vein in 80 per cent, and into the atrium in 16 per cent (all examples of common trunk). In one case (4 per cent) one vein drained into the upper lobe vein, and one into the atrium (Fig. 9).

In 32 per cent a small branch or branches drained a part of the middle lobe across the fissure into the vein of the (upper lobe) pectoral segment (V 2) (Fig. 4). In these instances the horizontal fissure between upper and middle lobes was incomplete.

In a single instance a small branch from the lateral aspect of the middle lobe drained into the subapical vein of the upper lobe (V 3).

In still another instance the anterior portion of the pectoral segment (upper lobe) drained into the medial vein (V 5) of the middle lobe.

In three specimens the injection technique was sufficiently coarse so that small vessels traversing the fissures may have escaped filling.

RESULTS

Having used this operative method during the past sixteen months only, 8 patients have been so treated (Table II). They ranged in age from 9 to 49 years. Four were male and four female. The postoperative hospitalization ranged from thirteen to thirty-two days and averaged twenty. The number of thoracenteses required per patient after operation varied from one to four.

In four instances the patients were studied by postoperative lipiodol bronchography to demonstrate the level of resection in the intermediate bronchus, and the roentgenogram of a case is reproduced (Fig. 10).

No patient has had empyema or a demonstrable fistula of the bronchial stump. All are living.

TABLE II. BILOBECTOMY

CASE	NUMBER	SEX	AGE (YR.)	DATE OF OPERATION	P.O. DAY OF DISCHARGE	DIAGNOSIS
J. K.	B92915	M	21	2/27/47	32	Chronic bronchiectasis, rt. mid. and rt. lower lobe
M. D.	B96788	F	40	5/13/47	23	Chronic bronchiectasis, rt. mid. and rt. lower lobe
V. S.	B92556	M	9	5/27/47	22	Bronchiectasis, all 5 lobes
J. S.	B97266	M	42	6/ 5/47	24	Chronic bronchiectasis
J. M.	B36248	M	49	1/17/48	17	Bronchiectasis and cystic disease, rt. lung
E. R.	B94432	F	28	2/ 3/48	17	Bronchiectasis, bilateral (previous left lower and lingulectomy)
M. B.	C6108	F	39	3/27/48	14	Tuberculosis, cavitation, rt. mid. and rt. lower lobe
N. T.	C7440	F	36	4/12/48	13	Post-tuberculous bronchostenosis and bronchiectasis rt. mid. and rt. lower lobe

DISCUSSION

The advantages of the bilobectomy procedure described here are several; first, a single and shorter bronchial stump deeply situated in the mediastinum; second, a single line of bronchial closure; third, an easy and adequate mediastinal pleural coverage with decreased opportunity for fistulous reopening and empyema.

The possible disadvantages are, first, the sacrifice of the lower lobe apical segment if this should prove to be uninvolved. In the absence of bilateral disease, this is not a serious objection. A second possible disadvantage is the requirement of an exact and detailed knowledge of the bronchovascular anatomy for this area, and third, the danger of compromising venous drainage from the upper lobe. In our small experience it has not been necessary to abandon this type of resection because of technical difficulties, although it is admitted that such might be the case with a very severely inflamed hilus.

SUMMARY

A technique for resection of the right middle and lower lobes as a surgical unit through the intermediate bronchus has been described.

Vascular variations based on 25 injection studies have been presented.

Results in 8 clinical trials are summarized.

The arguments for and against this procedure as compared to individual lobectomies performed seriatim are discussed.

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DISCUSSION

DR. WILLIAM M. TUTTLE, Detroit.—I have used this procedure in removing a lower and middle lobe in practically all such cases. A point which should be stressed is the treatment of the middle lobe vein because of the danger of injuring the vein to the upper lobe. In those patients in whom the middle lobe vein is not well demarcated I have secured all the vessels to the lower lobe as well as the middle lobe arteries and have then cut the bronchus and have left the middle lobe vein to the last. By such a method it is the only remaining structure sustaining the lobe. It is then easily and safely ligated and the lobe removed.

DR. EDWARD CHURCHILL, Boston.—Dr. Lindskog's statement that he has not been able to find this operation described in the literature means, I am certain, that he has not found as detailed a technical consideration as he has given us today. To keep the record straight regarding developmental steps, however, leads me to refer to the right lower and middle lobe lobectomy, with section through the intermediate bronchus "after isolation and separate ligation of the branches of the pulmonary vessels" reported in the JOURNAL in February, 1933 (page 257). This operation was performed on Aug. 10, 1931, for a tumor

classified first as adenocarcinoma and later recognized as bronchial adenoma. It was precisely the operation described by Dr. Lindskog today, with interlobar hilar dissection, primary closure of the intermediate bronchus, coverage of the stump with adjacent lung tissue, and temporary catheter drainage with suction to expand the remaining lobe. The patient is still living and well.

The most important landmark in this operation is encountered as the dissection is carried up the bronchus. This is the large tributary of the superior pulmonary vein called the "great upper lobe vein" by Appleton and "the posterior vein (V^3)" by Boyden and Scannell. It passes beneath the upper lobe bronchus and above the intermediate bronchus, to enter the superior pulmonary vein, and anomalies are rare except in its more peripheral tributaries. The bronchus may be divided at the inferior border of this vein or after carrying the dissection upward beneath it. The vein itself must be protected from injury.

DR. LINDSKOG.—I want to thank Dr. Tuttle for his discussion of the use of the posterior approach. We also have varied the approach a bit, and I think the posterior is useful in an occasional instance. I apologize to Dr. Churchill for not having seen his case report—it probably did not appear with a title we would recognize.*

I would like to conclude the discussion with a slide or two to further clarify the anatomy involved.

*Churchill, Edward D.: The Surgical Treatment of Carcinoma of the Lung, J. THORACIC SURG. 2: 254, 1932. Case 4 (page 257) reads as follows:

"On August 10, 1931, the lower and middle lobes of the right lung were removed after isolation and separate ligation of the branches of the pulmonary vessels supplying them. . . . The stump of the bronchus was fixed by two sharp hooks and a continuous suture of chromicized catgut used to close the aperture. The peribronchial and mediastinal tissue was drawn over the line of suture by interrupted mattress sutures. In separating the middle lobe from the upper lobe in the area of anatomic fusion, the electrocautery was employed. The denuded surface of the upper lobe thus produced was drawn over the bronchial stump and sutured to the mediastinum. A catheter was inserted between the ribs just above the diaphragm."

AN EXPERIMENTAL STUDY IN BRONCHIAL ANASTOMOSIS

TRUXTON L. JACKSON, M.D., PHILIP LEFKIN, M.D. (BY INVITATION), WILLIAM TUTTLE, M.D. (BY INVITATION), AND FOSTER HAMPTON, M.D.
DETROIT, MICH.

DURING the last decade increasing attention has been directed to healing and regeneration within the tracheobronchial tree. The advent of pulmonary resection with the necessary importance of a secure bronchial closure probably has furnished the greatest stimulus to study in this direction. Rienhoff, Gannon, and Sherman, in 1942, showed that the bronchus following pneumonectomy will heal securely with airtight closure of the pleura over the bronchial stump. Taffel, in 1940, published experimental work on the repair of tracheal and bronchial defects in dogs. Full-thickness windows were cut from the trachea and covered with mucosa. Within three weeks mucous glands were observed to appear in the submucosa. Daniel published experiments in 1948 concerning the use of rigid tubes to bridge defects of the trachea and primary bronchi. The regeneration of the tracheobronchial wall over the tube was closely observed and discussed. His experience indicated that fibroblasts in the early scar were the analage of cartilage cells. He believed that cartilaginous rings were formed from such anlage. Hanlon reported the use of gelatin sponge in the closure of defects of the bronchus and the closure of the bronchial stump following lobectomy. The sponge formed an adequate scaffold for the ingrowth of fibrous tissue and a wall for the ingrowth of mucosa.

The significant observation one may derive from the work of these authors is the remarkable powers of regeneration and healing within the tracheal and bronchial walls. It would seem to follow that the important factor in covering and healing of bronchial defects is an airtight closure that will allow ingrowth of connective tissue and epithelization. No matter whether the bronchus is being closed, defects in the wall are being covered, or a bronchial anastomosis is being effected, the process of healing is similar.

It was desired by the authors of these experiments to study end-to-end anastomosis of the bronchus, using dogs as the experimental animal. The problems undertaken were two and the experiment divides itself into two groups:

Group 1. Resection of segments of major bronchi and anastomosis.
Group 2. Creation of strictures within the major bronchi, their resection and re-establishment of bronchial continuity by anastomosis.

METHODS

Thirty-three dogs of nonspecific pedigree were used. The surgery was performed under endotracheal ether anesthesia, the lungs being inflated rhythmically by intermittent insufflation of the anesthetic. A small motor furnished the force for delivery of the air and ether to the lungs.

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Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

Group I.—Twenty dogs were used. The animals were divided into two groups depending on the method of suturing the bronchus.

(a) In ten dogs a cylinder of one of the main bronchi was removed and an anastomosis was performed by simple through-and-through interrupted 00000 silk sutures. All knots were placed on the outer surface of the bronchial wall. The pulmonary hilus was exposed, and the pleura over the bronchus was incised. Care was taken to open the pleura overlying the bronchus in a longitudinal manner. It was felt from previous experience that opening the pleura transversely could result in a significant interruption of the pulmonary plexus and the lymphatic drainage of the lung.

In the first five dogs a rubber shod clamp was placed on the proximal portion of the main bronchus, a one-fourth inch cylinder was removed, and the walls were approximated as just described. Penicillin, 50,000 units, was poured over the suture line and the pleura was closed over the bronchus. The lung was completely inflated before the chest wall was closed. The animals were bronchoscoped weekly and the suture line observed.

All animals developed a varying degree of stenosis and four had a stormy postoperative course. Penicillin, 50,000 units, was given intramuscularly twice daily and the bronchus was aspirated periodically. One animal developed an early progressive stenosis, lost weight, and was sacrificed within one month. An almost complete stricture was found at the suture line with a consolidated, suppurating lung distally. The bronchial wall was densely infiltrated with leucocytes, but there was complete epithelization. The suture line was red and edematous and sutures were lying free in the bronchial lumen. Two other animals developed a more slowly progressive stenosis, were chronically ill, and lost weight. Bronchoscopy showed complete epithelization of the wall but a gradual loss of lumen with accumulation of pus distally. These dogs were sacrificed in three and four months. Almost complete strictures were found. Both had local empyemas around the suture line. These were walled off pockets and a general empyema was not present. Both presented chronic suppuration of the lung with diffuse severe bronchiectasis.

This series of events was attributed very early to the use of a clamp on the bronchus. The two surviving animals were followed with bronchoscopy and were sacrificed at six and eight months. One developed a slowly progressive stenosis of the bronchus and repeated aspiration was done. The stricture became almost complete in six months and the dog was sacrificed. The lung presented a dense atelectasis and fibrosis with bronchiectasis but there was no frank suppuration. The bronchial wall at the suture line was markedly thickened and somewhat wrinkled. There was a fairly dense infiltration of lymphocytes in the wall and a heavy growth of scar tissue. The fifth animal was sacrificed in eight months. During the first two months there was very little evidence of any loss of lumen at the suture line and the area was completely epithelized. However, there was a gradual contracture at the suture line which in six months resulted in about 20 per cent stenosis of the bronchial lumen. In another two months there was no significant increase in this stricture. The animal was sacrificed at the end of eight months. His general condition was excellent. A 20 to 25 per cent loss of lumen was found due to a stricture at the suture line. The lung distally was entirely normal in appearance. It inflated well and on cut section was grossly normal.

It was felt that the use of a clamp of any type on the bronchus resulted in a high-grade stenosis at the suture line, with subsequent suppuration and bronchiectasis. At surgery, after the clamp had been removed, the bronchus resumed its normal shape, the lung expanded, and postoperative bronchoscopy revealed no immediate narrowing. However, the stenosis was rapidly progressive in one animal, less rapid in three, and insidious in the last. It was thought that the two instances of local empyema in this group represented a late breakdown of the suture line. The clamping and crushing of the bronchial wall produced injury to the area which led to the formation of scar tissue and to high-grade stenosis. When trauma from the clamp was excessive, a marked amount of granulation tissue formed and early stenosis resulted.

In order to effect temporary bronchial occlusion during surgery, a rubber balloon was thereafter used. This was placed in the proximal end of the bronchus, in place of the

clamp. An inflatable cuff on a small catheter was used at first, but this was occasionally unsatisfactory. The amount of air necessary to inflate it sufficiently varied and if too much air was used the cuff slipped into the trachea. To avoid this difficulty several sizes of balloons were made from old rubber gloves and the balloon tied shut with a piece of silk. The pressure in this type of balloon is low and it could easily be forced into the bronchus. It adapted itself readily to the conformation of the wall and by gentle traction on the silk, it was prevented from slipping into the trachea. Before the last two sutures were tied the balloon was punctured with a needle and withdrawn through the suture line. The distal end of the bronchus was isolated with sponges to keep aspiration of blood at a minimum.

Bronchoscopy was done on the five dogs in which a balloon was used immediately postoperatively and weekly thereafter. Following surgery there was a reddened edematous area at the suture line. Within five days there was a thin ridge of granulation tissue. Within two to three weeks most of the granulation tissue was no longer visible and the suture line had attained a smooth appearance. The area was slightly raised, injected, and edematous. With the passage of time this area flattened out and became white and glistening. However, at every point through which a suture pierced the mucosa there was some redness and edema. Even though the knots had been tied on the external surface, some had rotated and now lay in the lumen of the bronchus. Some of the sutures were completely covered with mucosa. The presence of the sutures in the mucosa presented for six to eight weeks a definite source of irritation and in most of the specimens a few could be seen four to five months later, though they were completely covered with epithelium.

Fig. 1.—Showing specimen three months after simple through-and-through anastomosis. Line of union is just proximal to the upper lobe orifice. Some of the knots have rotated into the lumen.

Fig. 1 is a photograph of a specimen at three months after anastomosis. The sutures are seen as described previously. There is a very slight ridge where the mucosal edges meet. The line of union is just proximal to the upper lobe orifice which was uneffected by the surgery.

These dogs were sacrificed at periods from one month to eight months, microscopic sections were taken through the suture line, and the specimens were preserved. It was found that at one month there was complete epithelization at the suture line and union of the bronchial wall by fairly dense connective tissue. Most of the leucocytic infiltration had dis-

appeared and mature scar tissue was present. The epithelium was low cuboidal in type. Fig. 2 is a photomicrograph of such a specimen. In the middle of the field just beneath the mucosa can be seen two pieces of silk which have been completely covered with epithelium. The wall is made up of dense connective tissue. In several areas cartilage can be seen undergoing degeneration. In some specimens within four to six weeks the low cuboidal epithelium has been converted into a fairly normal-appearing bronchial epithelium. Fig. 3 is a section of a specimen at one month. In this section the epithelium is early columnar in type. This is seen in the left portion of the field.

The only pertinent changes following this, in the animals sacrificed at longer intervals, lay in the fate of the sutures and the tendency to form a slight ridge at the suture line following contraction of the scar tissue. Around all of the sutures there was, in microscopic section, a significant foreign body reaction. Some of the sutures slowly worked into the lumen of the bronchus, were cast out, and the area was epithelized. Other sutures, especially those around a cartilage, remained in the wall and the endobronchial portion became com pletely epithelized. This epithelization of the sutures is demonstrated well in Fig. 2.

The early ring of granulation tissue in the lumen of the bronchus was constant in all of the dogs anastomosed in this manner. The presence of this tissue in the lumen was not desirable. It was necessary for the epithelium to grow over this ridge of tissue and this caused some loss of functional lumen, however, in several weeks this area flattened out. The presence of the sutures through the mucosa and lying in the lumen of the bronchus was a source of constant irritation within the bronchus. This seemed especially important when the suture line involved the wall of the upper lobe orifice or one of the lobar bronchi as it did in several of the animals. Here a moderate amount of granulation tissue, together with edema, was in one instance enough to prevent proper aeration and drainage of the lobe. To improve the suture line a very accurate approximation of the mucosa seemed important, to avoid the granulation tissue ridge. It was desirable to place the sutures so that as little as possible of the suture material would lie within the lumen of the bronchus. The use of an averting mattress suture seemed likely to satisfy in part these requirements.

(b) To test this hypothesis ten dogs were used. Thoracotomy was performed in the same manner as before. A balloon was used to plug the proximal bronchial segment. A single row of horizontal everting mattress sutures was used, thus turning up a very small cuff.

The actual technique varied somewhat with the size of the bronchus. In the larger animals, while removing a section of the bronchus, it was possible to cut close enough to the cartilage on either end of the removed cylinder to leave enough bronchial wall soft tissue to allow for closure without disturbing the cartilages. In others attempts were made to remove a cartilage without tearing its bed, and to use this tissue for the anastomosis. This proved tedious and usually resulted in tears through the bed. Therefore, in the smaller animals, the cartilaginous ring was cut across transversely, without cutting the mucosa, in three places to allow a cuff to be turned up without undue distortion. The sutures were placed close to the cartilage. When sufficient tissue was not present between the rings for anastomosis, the sutures were placed behind the cartilage ring, thus turning up a larger cuff. Immediately postoperatively, there was no raw surface at the suture line and a cleft was seen where the cuff was turned outward. Bronchoscopy was done on the dogs weekly. In most animals there was never a ring of granulation tissue in the lumen at the suture line. From the day of surgery the bronchial wall appeared smooth. During the first week there were no sutures visible through the bronchoscope. There was absence of the prominent redness and edema seen in the animals of group a. The dogs did less coughing and seemed to have a smoother postoperative course.

If a large cuff had been turned up the bronchus stretched out and in several weeks some of the sutures could be seen; however, even then, there was no granulation tissue present in the lumen.

Some of the sutures cut through the wall and were cast off into the lumen but this was not as constant as with the group a animals. The rest of the sutures were soon covered over with epithelium. At first one could see a groove where the cuff had been turned but

Fig. 2.

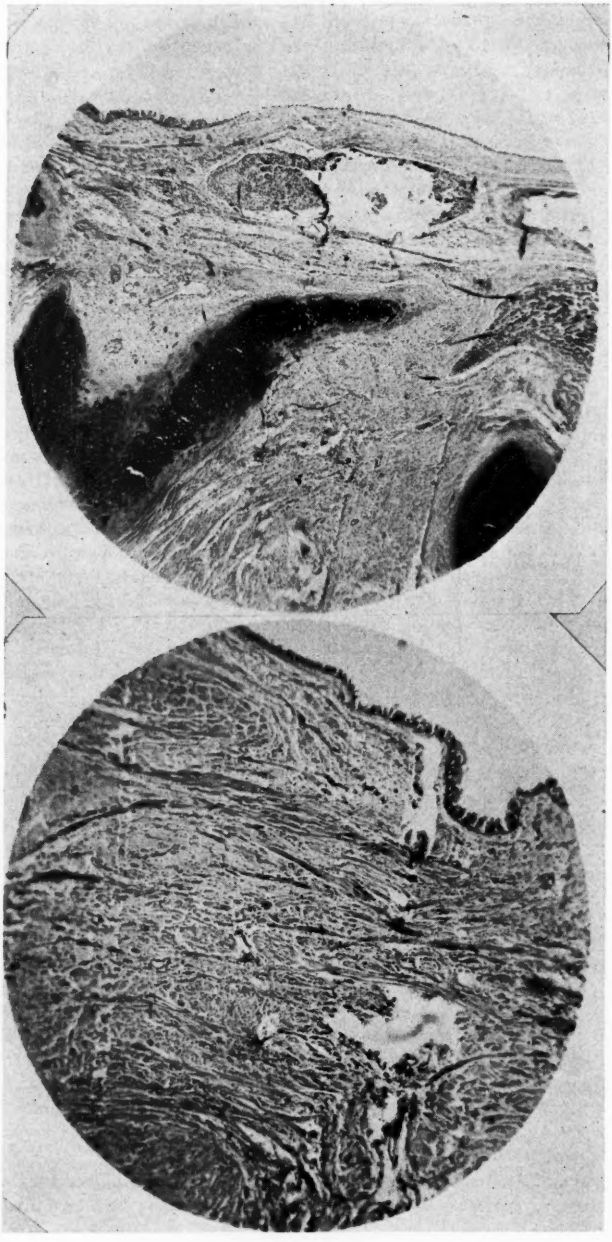

Fig. 3.

Fig. 2.—Photomicrograph of specimen six weeks after anastomosis. Just beneath the mucosa two silk sutures have been completely covered with epithelium. Low cuboidal epithelium is present. Degeneration of cartilage can be seen. (×75.)

Fig. 3.—Photomicrograph of specimen one month after anastomosis. One can see where the suture has traversed the well. Early columnar type of epithelium can be seen in the left corner. Dense connective tissue is present in the wall. (×125.)

this soon flattened out and the wall became very smooth with a few sutures visible completely covered with mucosa (bronchoscopic observations). Fig. 4 shows a specimen at three and one-half weeks, Fig. 5 one at eight weeks, and Fig. 6 one at ten weeks. In Fig. 4 the suture line has gone across the floor of the upper lobe orifice and there is a probe in the orifice of the upper lobe. Several of the sutures have cut through the mucosa, but no sutures are visible and there is very little reaction at the suture line. Fig. 5, presenting a specimen at eight weeks, shows several sutures to be barely visible but these are completely covered with epithelium. There is no longer the groove present seen in Fig. 4, there is no

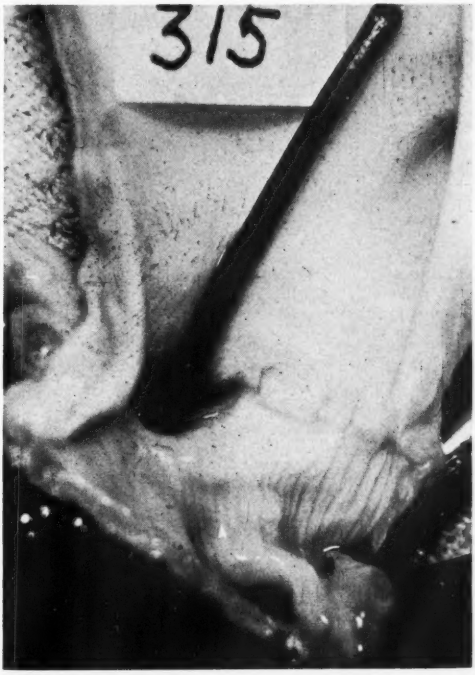

Fig. 4.—Photograph of specimen three and one-half weeks after anastomosis by cuff technique. Stricture of right main bronchus was resected. Suture line goes across floor of upper lobe orifice and a probe is in the orifice. Several sutures have cut through the mucosa but none are visible. Slight groove can be seen at the mucosal junction where the cuff has been turned.

inflammation at the suture line, and no loss of lumen from scar. In Fig. 6, at ten weeks, one suture is visible, the bronchial wall is entirely smooth, and there is no evidence of stenosis. It is difficult to identify the suture line from the mucosal surface but at the cut edge one can see the turned up wall. Fig. 7 is a photomicrograph of a specimen at two months. There is a slight groove in the mucosa where the cuff has been turned and it demonstrates how the entire wall has flattened out. There is a moderate infiltration with leucocytes, and fibroblasts are present.

It was felt that this method of suturing represented a definite improvement upon those in group a. In none of these ten dogs was there an appreciable loss of lumen at the suture line even at eight months. The lungs were grossly normal. Most of the improvement with this type of suturing lies within the first two to three months. In dogs sacrificed at six and eight months there was no great difference between the last dogs of group a and those of group b.

Group II. Creation of Strictures Within the Major Bronchi, Their Resection, and Re-establishment of Bronchial Continuity by Anastomosis.—Thirteen dogs were used. Stenoses were created in either main bronchus by the following methods:

(1) Injection of 30 per cent silver nitrate into the bronchial mucosa, 3 animals.

Fig. 5.

Fig. 6.

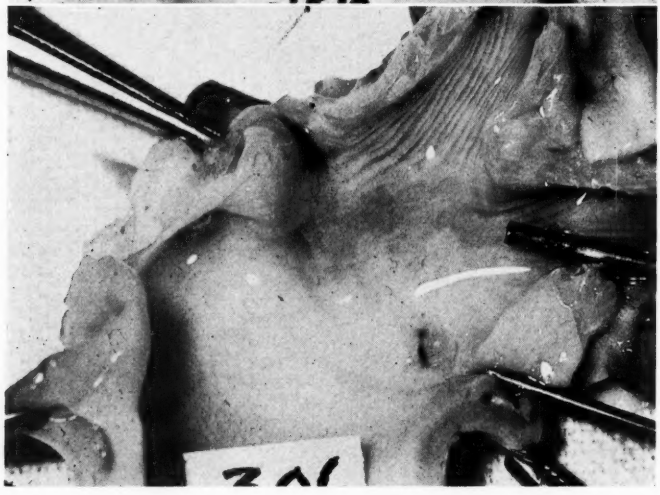

Fig. 5.—Photograph of a specimen eight weeks after anastomosis by cuff technique. A stricture of the right main bronchus had been resected. Two sutures are barely visible and completely epithelized. The groove seen in Fig. 4 cannot be seen here. The wall has flattened out. Line of anastomosis lies immediately in front of upper lobe orifice.

Fig. 6.—Photograph of a specimen ten weeks after anastomosis by cuff technique. A stricture of the main bronchus had been resected. Wall is smooth with no evidence of stenosis. One suture barely is visible. Suture line is difficult to identify but at the edge the turned up wall can be seen. A probe lies in the upper lobe orifice.

(2) Cellophane wrapper around the bronchus, 4 animals.
(3) Umbilical tape wrapper around the bronchus, 6 animals.

The use of silver nitrate proved difficult. It was necessary to inject the solution through the bronchoscope, making use of a long needle carrier, hypodermic needle, and syringe. The main bronchus is extremely short. Usually some of the caustic material escaped from the wheal or needle and ran down into the lobes. Painting with sponges involved the same difficulty. These procedures resulted in a severe bronchopneumonia and the ulceration and stenosis of the bronchus was not localized. The formation of the stenoses required numerous treatments with the silver nitrate. Three animals were treated in this manner. The time between the use of the silver nitrate and resection of the stenotic area varied between two and ten weeks.

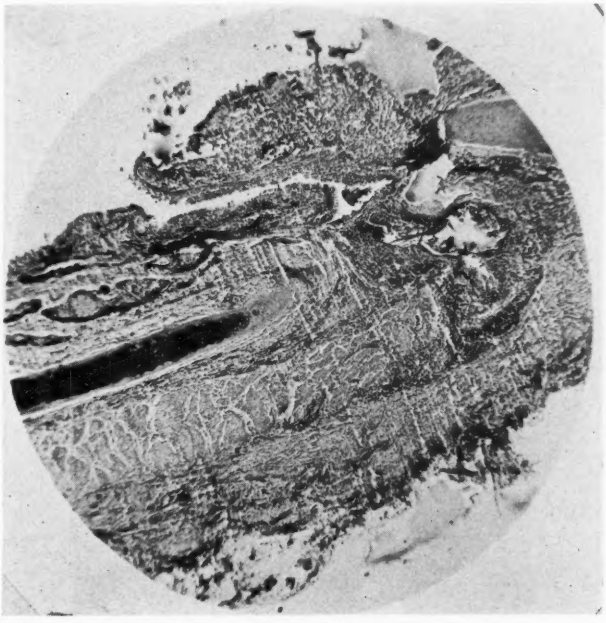

Fig. 7.—Photomicrograph of a specimen two months after anastomosis. The groove where the mucosa has been turned inward, can be identified. The wall has flattened out considerably. (×75.)

In the remaining ten dogs the chest wall was opened through the fifth rib bed, and the pleura opened and reflected off the bronchus. A mechanical stricture of about 60 per cent of the bronchial diameter was created by placing a cellophane wrapper (four dogs) or umbilical tape (six dogs) around the bronchus. The cellophane was tightened to give the desired stenosis and sutured together with 00000 silk. The umbilical tape was tied at the desired tension. The dogs were bronchoscoped and the stenoses visualized to see if the desired result had been accomplished. The cellophane had not been treated with polythene.

The use of cellophane was discontinued because it occasionally slipped, requiring another operation to reproduce the desired stricture. Bronchoscopy was done on the dogs weekly. If the animals developed obstructive symptoms, they were aspirated, given penicillin, and operated upon early. The time period between creation of the stenoses and the resection varied between thirteen days to two and one-half months. One dog developed a severe stenosis following silver nitrate treatments due to edema and ulceration. He was

operated on in thirteen days after the last application of the caustic and made an uneventful recovery.

In resecting the stenoses, the dissection was carried back to normal bronchial wall on either side. All surrounding scar tissue was dissected from the bronchus in order to allow greater mobility of the bronchus and prevent undue tension on the suture line.

Anastomosis was accomplished following the techniques described in Group I. In ten dogs the simple through-and-through method was used and in three the cuff method. The three dogs in which the cuff method was used experienced an uneventful postoperative course. At bronchoscopy no sutures were visible for the first two weeks, and the suture line presented very little injection with no visible granulation tissue. After two weeks several sutures were visible in two of the animals, by bronchoscopic examination.

Fig. 8.—Photograph of a specimen five months after anastomosis by simple through-and-through technique. Several sutures are visible though covered with epithelium. A stricture of the main bronchus has been resected. The upper lobe orifice is open, and the suture line goes across its floor.

The three dogs in which the cuff technique was used were sacrificed at three and one-half, eight, and ten weeks. Figs. 4, 5, and 6 are photographs of the bronchial specimens. In three and one-half weeks there was complete epithelization of the suture line, and a very faint groove at the mucosal junction. Fig. 4 presents these findings. Fig. 5, representing a specimen at eight weeks, shows several sutures to be barely visible. It will be noted that the suture line goes across the floor of the upper lobe orifice but there is no loss of its lumen. The line of anastomosis is smooth and not raised. Fig. 6 represents a specimen at ten weeks with no sutures visible and a smooth unraised line of anastomosis.

The ten dogs in which the bronchus was sutured by simple through-and-through sutures were sacrificed at periods varying from one to seven months. Bronchoscopy during the first weeks presented the previously described thin ring of granulation tissue at the line of union. Within two to three weeks epithelization had occurred. One dog, sacrificed at four weeks,

presented a 20 per cent stenosis. This was not due to scar tissue in the wall of the bronchus but to faulty placing of the sutures. Large bites were taken and the membranous portion of the bronchus was not accurately apposed. When the anastomosis was completed there was a partial stricture from the actual anastomosis.

Within six weeks numerous sutures were seen in the lumen with varying degrees of reaction around them. Fig. 1 shows a specimen at three months. Six sutures are visible. The wall otherwise is completely epithelized and there is no loss of lumen from the suture line.

Fig. 8 represents a specimen at five months. Several sutures were visible but completely epithelized. The mucosa was columnar in type and ciliated as seen in Fig. 9, which is a section through the bronchial wall at the suture line. The round-cell infiltration in the right portion of the field, beneath the mucosa, is due in part to the presence of a suture. The mucosal surface of the suture line was slightly raised. At seven months no sutures were visible on the mucosal surface. There was a slight ridge on the mucosal surface of the suture line, representing a slight loss of lumen from the anastomosis.

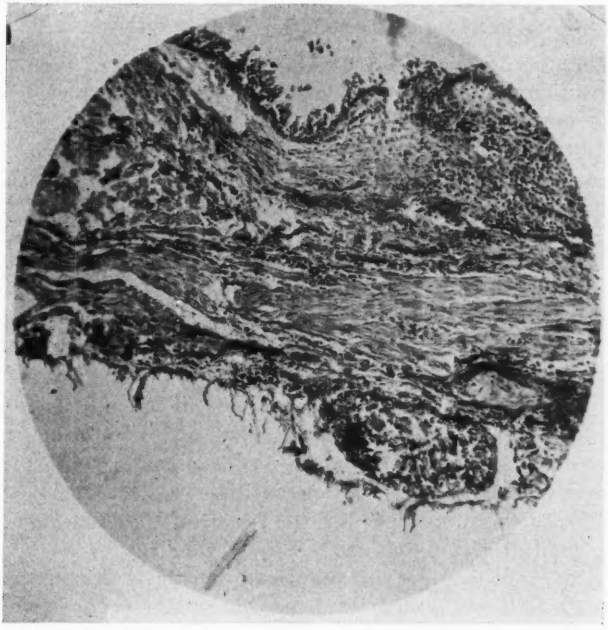

Fig. 9.—Photomicrograph of a section through the suture line five months after anastomosis. Fibers of a suture can be seen on the edge of the outer wall and there is considerable round-cell infiltration beneath the mucosa on the right, where a suture has cut through. The epithelium is ciliated columnar. (×125.)

In one animal a stricture of the left lower lobe was resected. The animal was sacrificed in two months. The lower lobe was grossly normal in appearance. There were two small ulcerations in the mucosa where sutures had sloughed out. There was approximately a 15 per cent loss of lumen from stricture formation but all of the lobular orifices were patent and the lobe well expanded.

In one of the dogs, it was found at operation that the tape used to create the stricture had cut through the outer surface of the bronchus and was completely covered. The stricture was difficult to identify, and it was necessary to open the bronchus to find the tape. It was completely covered by epithelium and lying within the bronchial wall. It was believed that it would have been cast off into the bronchus in time.

DISCUSSION

It is appreciated that the physical arrangement of the pulmonary hilus of a dog is more conducive to surgery than the bronchus in man. In the dog, the fissures are complete and the main bronchus is readily and easily exposed. The possible clinical applications of these experiments are therefore not clear. However, one can postulate several situations in which the procedure could be used should the bronchus prove accessible:

(1) Traumatic rupture of the bronchus
(2) Adenoma of the bronchus
(3) Benign tumor of the bronchus requiring resection
(4) Local stricture associated with trauma, foreign body, chemical burn, etc., with evidence of normal pulmonary parenchyma distally.
(5) Accidental severing of the bronchus during surgery.

In two of the dogs a Gelfoam sponge was placed over the outer surface of the suture line and the pleura closed in the usual manner. When these animals were sacrificed several months later a much denser area of scar tissue was encountered than was expected or found in the other animals. The papers of Hanlon and Daniel have demonstrated the manner in which Gelfoam acts as a lattice for the ingrowth of fibrous tissue. Because of the tendency to increase the amount of scar tissue at the anastomosis, its use was discontinued in the experiments on bronchial anastomosis. Ideally one wished to have only enough scar tissue at the anastomosis to secure union.

It would follow from these experiments, if one can achieve an accurate approximation of mucosa to mucosa, that the epithelium acts as a bridge for the ingrowth of granulation tissue in the outer wall and there is a minimum of scar at the union of the mucosa. In these experiments the use of horizontal mattress sutures, turning up a small cuff, offered a result superior to that when simple through-and-through sutures were used.

The use of silk carries some objections. It is not absorbable and the majority of the sutures are cast off into the lumen of the bronchus. If cast off they leave a path of granulation tissue through the wall to the lumen. If incased within the wall they cause a significant amount of scar tissue. In these experiments the silk was waxed in all but the first few to prevent dragging submucosal tissue through the needle holes. In one animal 00000 Nylon was used. This suture presented a smooth surface and was very easy to work with. Some animals are under observation now in which 00000 medium chromic catgut was used for the anastomosis.

In some of the specimens the suture line went across the upper lobe orifice. Healing occurred readily without atelectasis of the lobe or stenosis of the orifice. In these cases the use of the cuff technique is especially valuable. It prevents the ingrowth of granulation tissue between the mucosal edges, and there is less likelihood of stricture formation at the orifice.

From the results of the use of rigid clamps on the bronchus in the first five dogs of Group I (a) it would seem hazardous to use such a clamp on the proximal end of the bronchus in pulmonary resection. We feel this true not because

of the dense scar tissue that was formed, but because in two dogs bronchopleural fistulas with local empyemas occurred.

The specimens were preserved and mounted in gelatin after the technique described by Howard.*

CONCLUSIONS

1. The bronchus has been divided and anastomosed in thirty-three dogs.
2. Two methods of anastomosis were used, namely, a simple end-to-end closure and an everting cuff closure.
3. The occurrence of unsatisfactory incidents was much less in the everting cuff method.
4. Bronchial stenoses were produced and treated by resection and anastomosis with satisfactory results.
5. The problem and its clinical application has been discussed.

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DISCUSSION

DR. TUTTLE.—We have used this method in the human being. The patient was a man who had had a snare type of lobectomy done some ten years previously. He recently returned to us bleeding from the lung and a bronchogram revealed that he had a bronchiectasis of the lingula, which had not been removed at the time of the previous operation. Re-exploration and a lingulectomy were done. It was then realized that the dorsal division of the lower lobe had been left at the time of the snare lobectomy. In the process of cutting across the main bronchus above the dorsal division bronchus it was suddenly realized that because of the shortening which had occurred from the previous lobectomy, the division would have to come above the upper lobe bronchial orifice. When this situation was evident it was decided to sever the bronchus and anastomose the upper lobe bronchial orifice to the main left bronchial stem bronchus. This was done with interrupted sutures of fine silk. The postoperative course was uneventful with the exception of one incident of atelectasis on the fourth postoperative day. Bronchoscopy was done at this time and the suture line was well visualized and seemed to be well healed. He has made an uneventful recovery and the left upper lobe is completely aerated.

DR. ROLLINS HANLON, Baltimore.—I have enjoyed this presentation by Dr. Jackson and his associates. We all realize that results in experimental studies on animals cannot be applied without reservation to human beings. However, I am sure that the principles he has enunciated are valid.

Dr. Jackson tested the use of gelatin sponge as a supplement to conventional bronchial suture and discontinued its use because of the fibrous tissue reaction which was noted in the vicinity of the sponge. As we have pointed out elsewhere, this fibrous tissue reaction is beneficial in the early stages of bronchial repair, since it is capable of providing, without

*Dr. Eugene Woodruff was consultant pathologist in the evaluation of the specimens.

the use of sutures, the airtight closure that is essential in all types of surgery of the bronchus. Unless it be demonstrated that this fibrous tissue will subsequently constrict the bronchus, we should not reject the possibility of its use as an additional safeguard in bronchial suture.

I should like to refer to the use of gelatin sponge in another type of experiment, where it was used to repair window-like defects in the bronchial wall of dogs. In a high percentage of instances there was satisfactory healing, although in no case were sutures used to hold the material in place against the defect. On bronchoscopic examination several months later there was smooth healing without evidence of constriction. Similarly, in excision of the left upper lobe in the dog, with the bronchial stump covered merely by gelatin sponge without suture, bronchoscopy at intervals for several months showed smooth healing without granulations in the stump. This technique is suggested as an ancillary measure in the repair of bronchial defects occurring during excisional surgery of the lung or bronchus.

DR. OSLER ABBOTT, Atlanta.—I wonder whether or not a vertical figure-of-eight suture might not be more beneficial than interrupted mattress sutures, with less occluded blood supply. We have utilized this in recent work in resection on the lateral tracheal wall in carcinoma of the upper lobe. These sutures are not grossly visible on bronchoscopy, and I believe they are quite satisfactory as a method of anastomosis.

THE RECOGNITION AND CORRECTION OF CONSTRICTIVE PERICARDITIS

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THE successful correction of constrictive pericarditis is dependent upon two factors: (1) the clinical recognition and treatment of the disease at a time when the condition of the myocardium and circulatory apparatus will permit recovery once the heart has been released from bondage, and (2) upon an adequate pericardiectomy by the operating surgeon.

The recognition of the disease falls obviously and inevitably upon the internist, who must at all times be aware of its imminent possibility in any case of obscure ascites. It is said that a number of cases of constrictive pericarditis amenable to correction by operation are now improperly labeled tuberculous peritonitis, cirrhosis of the liver, valvular heart disease, or ascites of unknown origin.

The characteristic features common to most cases of constrictive pericarditis are: (1) increased venous pressure, (2) some form of peripheral edema associated usually with ascites or pleural effusion or both, (3) a quiet heart with normal blood pressure, and normal heart sounds, (4) an electrocardiogram exhibiting a low voltage in the QRS complex and inversion of the T waves, and occasionally (5) roentgenographic evidence of a calcified pericardium. The heart may be normal, slightly larger, or smaller than normal in size. When a febrile illness accompanied by pericardial effusion is followed by reduction in size of the heart, and by signs of cardiac failure such as ascites, pleural effusion, and increased venous pressure, one should strongly suspect the development of constrictive pericarditis.

In the surgical correction of the disease, two points must be strongly emphasized: (1) an operative approach that permits ready access to all critical areas requiring decortication, (2) an adequate decortication of the heart, including liberation particularly of the right heart and of the inferior and superior venae cavae. Exposure of the heart through the left parasternal incision as usually practiced is considered quite inadequate, as is also the transthoracic approach through the fifth or sixth interspace. Both these incisions serve adequately for exposure of the left side of the heart, but experience indicates that it is the right side of the heart that requires the more complete decortication, and therefore a more complete exposure of this side is imperative.

Moreover, decortication of the thick-walled left ventricle is fraught with much less danger than is the removal of the pericardium over the thinned-out right ventricle and over the normally thin right auricle and the two venae

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From the Stanford University School of Medicine.

cavae. It is quite probable that inadequate exposure was a factor in some of the twenty-one recorded deaths on the operating table.

As indicated above, the pericardium over the left ventricle has not in our cases been as greatly thickened nor as "oppressive" as the pericardium over the right heart and the two caval vessels. An explanation for this may lie in the greater and more forceful pulsating action of the left ventricle which forces the irritating pericardial fluid of the preconstrictive period of effusion into the less active and more quiet areas with consequently greater inflammatory excitation of the overlying pericardium. If the strongly pulsating, highly muscular left ventricle can be hampered visibly in its activity by a constricting pericardium as seen at fluoroscopy, how much more vulnerable to such constriction would be the more easily compressible right heart and the superior and inferior venae cavae as they lie in the intrapericardial space. The effects of such compression have been studied in our experimental laboratory. Constriction of the inferior vena cava to one-half its normal caliber in a 14 kilogram dog produced a permanent ascites in approximately seven days. Constriction of the pulmonary artery to approximately one-half its normal caliber led to the development of an ascites in about seven days. Constriction of the superior vena cava alone above the azygos vein produced no trouble, but when constricted below the entrance of the azygos vein, a pleural effusion occurred on about the ninth day. This last observation suggests that the pleural effusions so commonly observed in the presence of constrictive pericarditis may not be due necessarily to compression of the left heart but to superior vena caval constriction. Even more imperative, therefore, is the need of decorticating the superior vena cava.

The thickened pericardium lying between the inferior border of the heart and the diaphragm is also a critical structure requiring excision. Probably as the result of gravity, the irritating pericardial fluid of the effusion period, which usually precedes the scarring, is directed to the bottom of the pericardial sac, thus subjecting the diaphragmatic pericardium to marked inflammation and, therefore, to marked thickening and marked subsequent contraction. This thickened pericardial sheet anchors the heart rigidly to the diaphragm, so that as the latter descends in inspiration, the heart is hampered even further by traction resulting in limitation of its filling and of its contraction. It is this increased restriction of cardiac filling and contraction due to the descent of the diaphragm to which is ascribed the momentary disappearance of the pulse, the so-called paradoxical pulse that invariably accompanies constrictive pericarditis.

The calcified and thickened pericardium on the posterior aspect of the heart cannot and need not be removed, but it is important to recognize that fibrous tissue left behind will continue to contract, that, therefore, the removal only of the easily accessible anterior pericardium is quite inadequate, and that a satisfactory pericardiectomy must include excision of the constricting envelope beyond the left cardiac border, beyond the right cardiac border, and beyond the inferior cardiac border. This *beyond the border* decortication

is necessary in order that the scar that remains may not, in contracting further, enclose the heart in its grip.

It is obvious that to perform such an extensive pericardiectomy, a truly adequate exposure of the heart is necessary. This is best achieved through a limited median sternotomy from xiphisternum to the second intercostal space where a transverse incision through the sternum permits lateral displacement of the bisected sternum and the attached ribs.

The objection that in median sternotomy both thoracic cavities may be entered is no longer valid since intratracheal anesthesia is usually employed. A rent into the left pleural cavity can usually be avoided or can be closed successfully, but it is almost inevitable that the right thoracic cavity be entered if adequate liberation of the two venae cavae is to be achieved. Following careful displacement of the pleura lateralward on both sides, the pericardium is incised over the area of the left ventricle and is cautiously mobilized beyond the left border of the heart as far laterally as the left phrenic nerve (if it can be identified) which should not be injured; the pericardium over the right ventricle is then mobilized anteriorly, with excision of the pericardium overlying the pulmonary artery, the ascending aorta, and the superior vena cava. The right border of the heart is freed so as to yield a good view of the superior and inferior venae cavae. Inferiorly the heavy, frequently calcified pericardium lying between the inferior border of the heart and the diaphragm is excised from the inferior vena cava on the right border to the apex of the left ventricle on the left border. In this excision normal muscle bundles of the diaphragm should be exposed.

The right auricle must be liberated with caution if direct removal of the overlying pericardium is attempted. That its removal is possible was proved by our experiences, but if this seems too hazardous, the pericardium may be incised both along the auriculoventricular groove and at the base of the heart, leaving the intervening pericardium attached to the auricle. This has the effect of liberation and should permit the desired expansion of the auricle.

The closure of the median sternotomy is easily effected by the use of two or three No. 20 stainless steel sutures applied not to cartilage but to the bony part of the sternum, a precaution designed to avert infection in such poorly vascularized tissue as cartilage. The prepectoral fascia is mobilized on both sides for approximation in the midline with interrupted silk or cotton sutures.

We consider removal of the thoracic wall overlying the heart as unnecessary. In constrictive pericarditis the heart is limited not by the bony thorax but by the pericardium.

Because of the large area of denuded and traumatized tissue produced by pericardiectomy, sometimes performed in the presence of active tuberculous granulation tissue, there may be a considerable outpouring of wound fluid necessitating drainage of the operative site. This drainage has been effected by deliberately incising the right pleura along its mediastinal border where it has not already been opened and providing for removal of the fluid from the

right chest either by repeated aspirations or by intercostal tube drainage. In the seven cases in which median sternotomy was used, complete primary healing of the operative wound has occurred, even in the presence of an active tuberculous pericarditis in four cases.

A useful tool in separating the heart from the pericardium is the so-called "peanut" dissector, a small round pea-sized bit of gauze in a curved clamp. By painstaking slow dissection, now blunt now sharp, the proper cleavage plane can be maintained, but it is easily lost if speed rather than safety is the watchword.

Bigger's suggestion to retain the pericardium back of the advancing edge of dissection between pericardium and myocardium may be lifesaving in case the myocardial wall is accidentally perforated, or excessive bleeding is encountered. Resuturing the liberated but still attached pericardium to the myocardial surface may effectively control such perforation or bleeding.

Selection of the optimum time for operation may be difficult, and must be determined by conditions present in the individual case. In the absence of fever, and in the presence of calcification, which in itself is evidence of a long-standing chronic state, the detrimental effects of the disease are wholly mechanical in origin and the operation may be done at any time following a period of bed rest, during which the elimination of tissue fluids is promoted by a low sodium diet and by chemically induced diuresis. Optimum nutrition with supplementary vitamins should be stressed and the thoracic and abdominal cavities should be emptied of their fluid as completely as possible by aspiration just before operation.

When the signs of compression are accompanied also by signs of acute inflammation, the problem becomes twofold: control of infection and correction of the mechanical obstruction to the normal circulation of the blood. The immediate treatment of the infection obviously requires rest in bed, optimum nutrition including supplementary vitamins, the administration of penicillin and streptomycin on the assumption of tuberculosis since tuberculosis usually cannot be proved or disproved until operation, and the correction of anemia. Improvement will be apparent from the reduction in fever, lowering of pulse rate, and decreased sedimentation rate. Operation may be delayed until such improvement is manifested, but should not be delayed long if the mechanical disturbances of compression are incapacitating and progressive. Under these conditions, the sooner the compression is corrected the better will be the ultimate results. In Case 4 only seven months elapsed from the onset of symptoms due to acute pericarditis with effusion to pericardiectomy for constricting pericardium; in Case 5, ten and one-half months elapsed. In both cases tubercle bacilli were demonstrated on culture of pericardial fluid removed at operation.

The administration of streptomycin decreases the hazard of operating in the presence of active tuberculous pericarditis. In Case 4, streptomycin was reserved for the immediate postoperative period, since this was considered the crucial period of recovery, and its administration was continued for three months after operation.

In Case 5, on the assumption of an active tuberculous pericarditis, streptomycin 1 Gm. daily, was administered from Nov. 27, 1947, to March 23, 1948. Pericardiectomy was performed May 15, 1948, and streptomycin, 2 Gm. daily, was again administered from May 10 to July 6, and 1 Gm. daily from July 6 to Aug. 10, 1948.

SUMMARY

In 265 recorded operations for constrictive pericarditis, 21 deaths occurred on the operating table, 48 deaths occurred in the early postoperative period, 118 cases were considered cured and 44 cases improved.

A satisfactory and adequate pericardiectomy must include liberation of all borders of the heart and of both venae cavae. The inferior cardiac border must be liberated by excision of the pericardium lying between the heart and the diaphragm.

Persistence of ascites following pericardiectomy is evidence of an inadequate decortication and demands reoperation and removal of more scar, rather than an omentopexy or Talma operation.

To achieve the exposure necessary for an adequate inspection and decortication of the heart, a median sternotomy with transverse division of the sternum in the second interspace is recommended. The sternum is reapproximated by several stainless steel sutures inserted through bone, not through avascular cartilage.

The wound should be drained, preferably into the right pleural space from which the fluid can be removed either by aspiration or by intercostal drainage.

In patients suspected of having tuberculosis or in those in whom evidence of active inflammation is present, the preoperative preparation should include a prolonged period of bed rest with optimum nutrition, and the administration of penicillin and streptomycin. Operation should not be deferred unduly if the symptoms of compression are incapacitating, unaffected by therapy, and progressive.

Operation was performed in nine cases: five of unknown etiology, with one death and four cures; and four of active tuberculous pericarditis, with marked improvement in all, and with probably complete cure in two.

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DISCUSSION

DR. ALFRED BLALOCK, Baltimore.—Our experience confirms that of Dr. Holman. We, however, use an incision which extends from the top to the bottom of the sternum; that is, the sternum is split from the suprasternal notch to the upper abdominal region. I disagree with Dr. Holman that a Lebsche knife is an especially traumatic instrument. It is only the uppermost part of the sternum which consists of hard bone and the rest of it is split quite easily. In five consecutive cases we have used this incision and it has been our impression that the venous pressure has declined much more rapidly and the ascites has disappeared more rapidly than in previous cases in which we have used a left or right parasternal incision.

Recently we used this median sternotomy in approaching the pulmonary valve of a patient who was diagnosed as having pure pulmonic stenosis. It gives an excellent exposure of the right ventricle and of the pulmonary artery, as Dr. Holman has stated, and a good direction in which to work with a valvulotome. I do not think, however, that this incision would be very useful in an approach to the mitral valve or the aortic valve.

DR. JULIAN JOHNSON, Philadelphia.—We have used an incision that is a little different in order to obtain the same general magnitude of exposure. It is a transverse incision which extends from the midaxillary line on one side to the midaxillary line on the other.

It is made in the third or fourth interspace and divides the sternum but no ribs. By placing the rib spreader between the two ends of the sternum a wide exposure may be obtained. It has the advantage of affording excellent exposure to both sides of the heart as far around as desired.

DR. ARTHUR S. W. TOUROFF, New York.—I was very much impressed by Dr. Holman's presentation of the trans-sternal approach in cases of constrictive pericarditis. I, personally, favor a free left-sided, transpleural incision for the reason that it appears to be less traumatic and also affords a better exposure of the apex and posterior surface of the heart than the incision which Dr. Holman advocates. (Slides.) I make a submammary incision in the fifth, left, intercostal space and divide the fourth and fifth costal cartilages. By carrying the incision from the left border of the sternum well into the axilla, and retracting the edges of the wound widely, one is able to get an excellent exposure of the heart. In performing pericardiectomy through this incision, it is possible to decorticate the major portion of the anterior and diaphragmatic surfaces, the entire apex and a large part of the posterior surface. The exposure of the left lateral and posterior aspects of the heart are so complete, as to make it essential to identify and carefully retract the left phrenic nerve as it courses over the pericardium. By grasping the thickened pericardium as it is freed from the anterior surface of the heart, and making strong traction toward the left, it is surprising how far the decortication can be carried toward the right side of the heart. The best evidence of the adequacy of the approach is the fact that in none of our cases has the end result been unsatisfactory and in none has it been necessary to reoperate. I agree with Dr. Holman that decortication of the right heart is essential, for one of the most important features of constrictive pericarditis is the inability of this portion of the heart to fill adequately. As regards complete freeing of the superior and inferior venae cavae, I am not sure that it is essential. I am certain that I have not been able to do this through the incision which I have used, and yet all of our results have been excellent. Accordingly, I am inclined to the view that unless the cavae are completely occluded—which is seldom, if ever, the case—an increased rate of blood flow through the partially constricted cavae tends to compensate for the narrowed caval lumina. Under such circumstances freeing of the right heart, rather than the caval areas, has yielded entirely satisfactory results.

DR. LOUIS R. DAVIDSON, New York, N. Y.—I rise to correct an impression created by Dr. Holman to the effect that using a Lebsche knife is a dangerous procedure, by virtue of the fact that the patient is markedly shocked thereby. I am in full accord with Dr. Blalock's remarks in this connection. I have used this instrument in thirteen cases of chronic constrictive pericarditis. It has also been used in the case of myasthenia gravis and also in cases of mediastinal exploration for parathyroid tumors. In no instance has it been regretted that the Lebsche knife had been used. We are firmly convinced that it is not traumatizing. In addition, and with very little difficulty, the surgeon can curve his osseous incision.

When Dr. Holman related he took cultures from the pericardial fluid, it brought to mind that one of these thirteen patients operated upon was proved to have had actinomycosis.

I regret that Dr. Holman's customary careful technique does not permit him to use a Lebsche knife, which I have found to be a splendid instrument, particularly in this field.

DR. R. A. DORNER, Des Moines.—Dr. Holman merely mentioned the use of streptomycin in patients with tuberculous pericarditis. Years ago, as you all know, patients with tuberculous pericarditis were carried along until it was felt that the active inflammatory process had completely subsided. In 1947 I operated upon a white man, aged 55 years, from the medical service of Dr. Arthur Wise of the Iowa State Tuberculosis Sanatorium. This patient, with active tuberculous pericarditis, was losing ground during the "waiting period." Fluid from the pericardial sac contained tubercle bacilli; and an inoculated guinea pig was positive. The pericardiectomy was carried out through a left sternal border approach removing as much pericardium as possible. The patient improved for a time and then began to develop increasing ascites. I therefore made a right-sided incision and removed all of the pericardium from the edge of the left-sided operation down to and including the pericardium

around the inferior vena cava. (From this experience I would agree thoroughly with Dr. Holman that the venae cavae should be released. One could see the blood rush into and dilate the intrapericardial portion of the cava as the pericardium was freed from around it.) I then proceeded to remove the pericardium from around the superior vena cava in a similar manner.

Streptomycin was given to this patient as follows: Preoperatively: 250,000 units every three hours the day before surgery and continued in this dosage postoperatively for three months. Five hundred thousand units were placed in the operative field.

This patient's convalescence was complicated by bilateral pleural effusions necessitating thoracenteses but these and generalized edema subsided quite rapidly after the second operation.

This patient had no evidence of tuberculosis elsewhere in the body; and under streptomycin therapy, even though there was active tuberculosis at the time of the pericardiectomies, he regained his health and at the present time appears well. I think the point should be emphasized that with streptomycin therapy patients with active tuberculous pericarditis can be operated on and, perhaps, should be operated upon quite early after onset of symptoms.

DR. CAMERON HAIGHT, Ann Arbor, Mich.—The incision which Dr. Holman has described undoubtedly gives a better exposure of the right side of the heart and the inferior vena cava than does the conventional flap incision as described by Schmieden. We have modified the latter incision, however, by extending the inferior arm laterally and have found it to be completely satisfactory. This modified incision not only gives adequate exposure of the anterior aspect of the heart, thereby allowing decortication of all of the right ventricle, but more importantly it gives an adequate exposure of the entire surface of the left ventricle, allowing the removal of the pericardial scar, and epicardial scar if present, as far posteriorly as the point of entrance of the inferior vein into the left auricle. With this incision the angle of approach to the heart is from an anterolateral direction, rather than from an anterior direction, as is the case with the flap and the sternal splitting incisions. The operation is done transpleurally.

During the last one and one-half years it has been our practice to drain the pleural space postoperatively with an airtight intercostal tube. Formerly, when using the extrapleural flap incision, the pericardial wound was drained into the pleural space by an intentional opening of the pleura before closure of the wound, and the subsequent effusion was removed by thoracentesis. If an obliterative pleuritis had occurred, the pericardial wound was drained locally with a Penrose drain. In these cases we observed a tendency for a temporary formation of new pericardial scar due to incomplete drainage of the serosanguineous effusion and a resultant fibrinous deposit on the heart. Convalescence was at times considerably delayed until the new scar had thinned. In order to minimize the tendency for the reformation of pericardial scar, we now drain the pleural cavity with an air-tight intercostal tube. Should the pleural space be obliterated by adhesions, an intrapleural pneumonolysis of the lower one-half of the lung is done, so as to form an actual space adequate for drainage. As a result of the wide decortication of both ventricles, together with the use of drainage of the pleural space, the postoperative convalescence has been more rapid than formerly, and the return of cardiac function has been uniformly better than with the previous plan of management.

DR. EDWARD D. CHURCHILL, Boston.—It is of interest that at the time Dr. Holman has been moving toward the right, my own position has been shifting to the left. And somewhat paradoxically, if the politically derived metaphor is continued, I have become less radical while doing so. The impediment to the action of the heart caused by constrictive pericarditis seems to me to center in the restriction of ventricular action, and distortion of auriculoventricular channels. This change in emphasis has been based on the careful observation of patients that have not been totally relieved by the operation shown by Dr. Holman. Studies with cardiac catheterization have pointed toward difficulty on the left side of the heart; consequently we have made a more determined effort at the initial operation to expose fully this area. The phrenic nerve is identified, dissected from the pericardium, and suspended so that one may work under it. The dissection is carried

back along the left auriculoventricular groove. The entrance of the pulmonary veins into the left auricle is exposed and liberated. I believe this is a crucial area because residual scarring at that point may simulate advanced mitral stenosis.

DR. J. R. HEAD, Chicago.—Of the thirteen patients who underwent surgery at Hines Hospital, there was a striking difference in the operative results when one compared the patients resected early against those resected late in the course of the disease. In the group of advanced cases, five patients were operated on, three showed moderate improvement, one showed no improvement, and there was one immediate postoperative death. In contrast, there were eight cases resected in the less advanced group with excellent results in all. This emphasizes the desirability of early operative intervention. In the far advanced cases, we have often found spicules of calcium with mushroomlike ends invading the myocardium and making its removal from this already weakened muscle very risky if not impossible.

The problem of contacting patients during the early phase of the disease is obviously difficult. The diagnosis of acute pericarditis is frequently overlooked and the patient may be relatively asymptomatic until the terminal stages of the constriction. Because of the good results with surgery early in the disease, Dr. Lyle Baker, Chief of Medicine, has established the policy of careful follow-up studies in all cases of acute pericarditis. If with the absorption of the effusion and return of the heart size to normal there is decreased pulsation on fluoroscopy and associated with this an increasing venous pressure and circulation time, it is then apparent that compression is taking place. If this compression continues to progress after a period of observation, operation is indicated providing the disease is stabilized as indicated by the patient's temperature and sedimentation rate. Antibiotics have helped to shorten this stabilization time and allow these patients to come to surgery at an even earlier and more advantageous stage of the disease. While only comparatively few patients who suffer from acute pericarditis will develop chronic compression, it is urged that they be followed closely and operated on early when evidence of progressive compression is confirmed.

DR. E. E. AVERY, Chicago.—The etiology of one of our cases of acute constrictive pericarditis with resection at Hines Hospital proved to be an organized hemopericardium. This young Negro man suffered a stab wound of the heart, and when first seen had an obvious cardiac tamponade. The heart size gradually returned to normal size but there was a progressive decrease in cardiac pulsation on fluoroscopy with increasing venous pressure and circulation time. Although we could find no reference to this condition, we felt that the pathogenesis was probably analogous to that of an organizing hemothorax, as has been so well described by Langston, Tuttle, and Samson. With this similarity in mind, two months were allowed to pass before pericardiectomy was done so that the clot would have sufficient time to organize and thereby facilitate decortication. At surgery the thickened pericardium with an adherent organized clot was resected. The epicardium was also covered with an organized fibrinous clot approximately one centimeter in thickness. A plane of cleavage was developed and the clot was easily stripped from the heart with gentle dissection. We do not know how often this situation may occur in hemopericardium, but we do feel that these cases should be carefully followed for evidence of progressive compression, and that the optimum time for decortication is probably six to ten weeks, at which time the clot is not densely adherent but is sufficiently firm to peel easily.

DR. HOLMAN.—The approach through the left thoracic cage seems to me to have certain inherent dangers of not exposing that portion of the heart which is most vulnerable to trauma and to accidental tears while freeing the pericardium from the right side of the heart, which I believe we all agree must be liberally decorticated. Accordingly, I would be very hesitant to use an approach that does not give good access to the right auricle as well as the right ventricle.

I think most writers are agreed that it is the inflow to the heart that is most impeded by constrictive pericarditis rather than the outflow, and it is the obstruction to inflow to which we ascribe the predominant symptoms of effusion, ascites, and peripheral edema, hence, the greater need of liberating the venae cavae and the right heart.

A METHOD FOR EXPOSURE OF THE CARDIAC SEPTA

An Experimental Study

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MANY investigators have successfully created defects of the cardiac septa. In more recent years, these have been done chiefly by Cohn,[1] Murray,[2] Martin, Essex, Burchell, and Edwards,[3] as well as by Blakemore,[4] Blalock and Hanlon,[5] and others. With the exception of the method of Blalock and Hanlon, these have been punch wounds or stab wounds of the septa produced blindly. These latter authors excised a portion of the posterior margin of the interatrial septum under direct vision.

An instrument has been devised by which the right side of the heart, either the right atrium or the right ventricle, may be opened and the septum exposed for varying lengths of time. The size of this exposure varies according to the instrument used and to the size of the heart to which it is applied. The septum, either the interatrial or the interventricular, may be exposed over a distance of 2 to 2.5 cm. in diameter. Various technical procedures can be carried out on the septa under direct vision. The incision in the right side of the heart is then closed.

Reference has been made in the literature to the interatrial septum being somewhat horizontally placed.[6] In fact, this has been given as the reason why the blood flow is from left to right in interatrial defects, the left antrium said to be superimposed or superior to the right. By more recent examination of the cardiac dynamics, especially by venous catheterization, it has been found that the actual pressure in the left atrium is greater than that in the right, which accounts for the left to right flow. In the dog, the right atrium is actually a little higher than the left.

The instrument consists of a double ring structure. The proximal ring is a large one, two to three inches in diameter, while the distal rings, which are placed at right angles to the former, are from 1.7 cm. up to 2.5 cm. in size (Fig. 1). The distal rings can be varied in size according to the size of the heart to which it is applied. Inasmuch as the right side of the heart, especilly the right atrium, is slightly larger than the left, the ring of the clamp which is to be applied to the left side of the heart may be slightly smaller than the right, thereby producing less obstruction to the circulation on the left side of the heart.

EXPOSURE OF INTERATRIAL SEPTUM

In the application to the atria, the large proximal ring encircles the base of the heart and the outflow tracks, while the distal rings approximate the lateral walls of both atria against the septum (Fig. 2). When the clamp is in place, there is no obstruction to the outflow of the ventricles. There is sufficient space around the distal rings when applied to the atria to permit blood to reach the

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ventricles. Within the circle of the ring which collapses the atria, a vertical incision is made in the right atrial wall as large as the ring of the clamp permits. After the right atrial wall has been incised, a few interrupted sutures are placed in the edges of the incision for later closure. These sutures are placed at this time so that, if the heart shows signs of failure, they can be pulled up and the clamp released, thereby resting the heart and allowing it to regain its full function. The clamp is then reapplied over the incision. Upon incising the right atrial wall, the interatrial septum is in view throughout the circumference of the

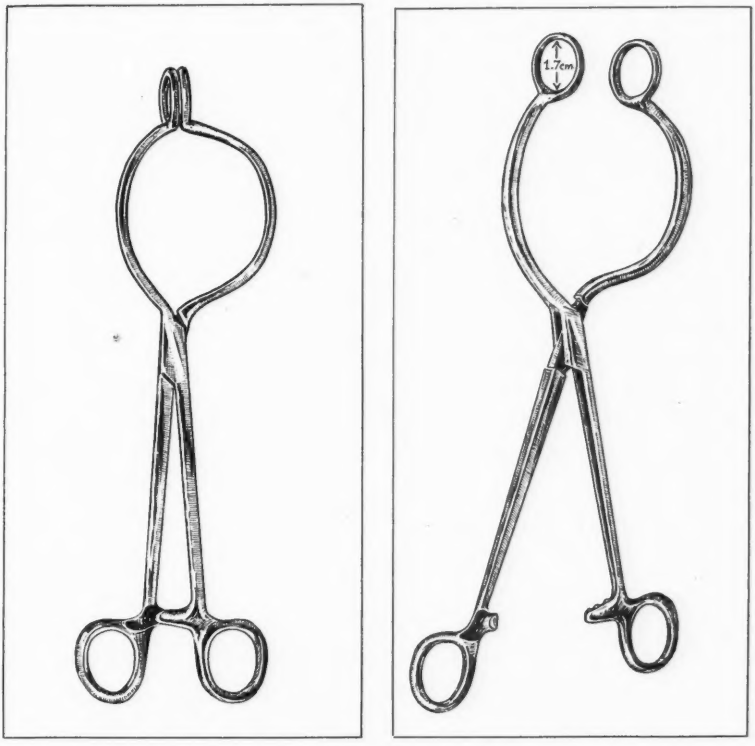

Fig. 1.—The instrument used for exposure of the cardiac septa.

ring (Fig. 2, inset *a* and *b*). In the application of the clamp to the atria, the lateral wall of the left atrium is situated far posteriorly and the septum lies directly beneath the right atrium. One limb of the clamp, therefore, completely encircles the base of the heart and comes to rest to the right side of the outflow tracts. When the clamp is in place, obviously there is some obstruction to the atrial blood flow, but this is not sufficient to interfere seriously with the cardiac output for short intervals.

The dogs have been anesthetized with procaine solution intravenously. After the heart has been exposed, it has been further anesthetized with procaine

solution topically. When the instrument is slowly but progressively applied to the atria, there may be some slight conduction disturbances which seem to disappear after the clamp is once firmly in place. During the remainder of the time the clamp is applied to the atria, the heart is regular in rhythm. Too quick a clamping of the atria or too rapid a release of the clamp sets up conduction disturbances which soon right themselves. The length of time which the heart will withstand the clamp in place varies considerably. Some animals

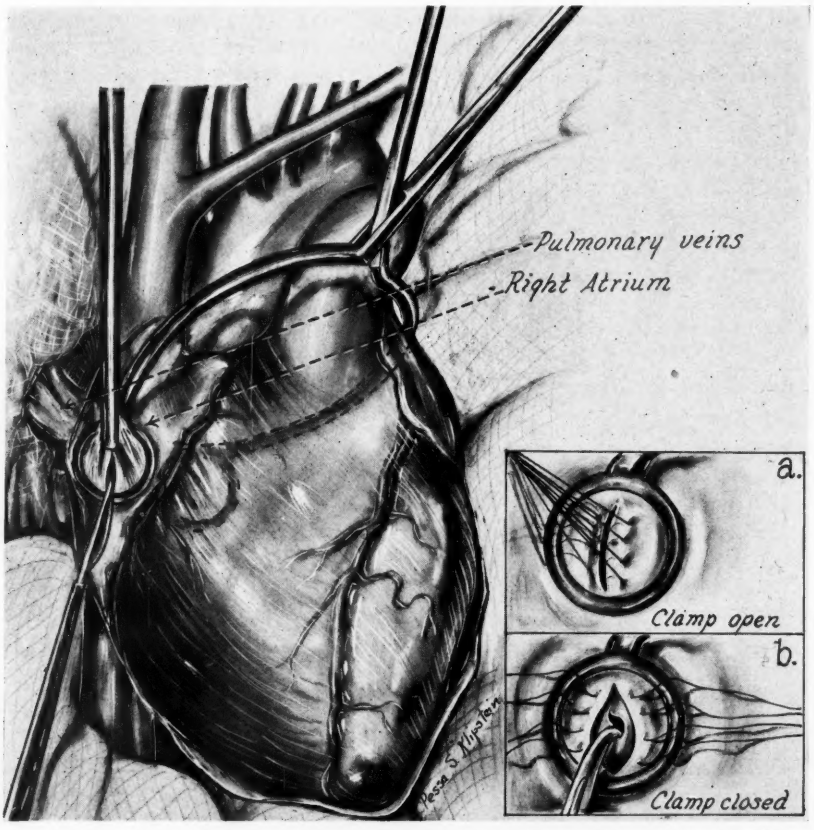

Fig. 2.—Showing instrument applied to atria. Inset *a* shows sutures in place and clamp released. Inset *b* shows clamp reapplied and defect of interatrial septum being made.

have withstood the clamp in place for thirty minutes, at the end of which time there was no sign of cardiac weakness or failure. Other hearts have withstood the clamp only a few minutes, perhaps three to five minutes, when they showed evidence of failure and the clamp had to be released. If the clamp remains on after there are signs of poor heart function, the ventricles eventually go into fibrillation and the heart dies. Apparently the reason that some hearts have withstood the clamp in place for so long a time is because of the size of the heart

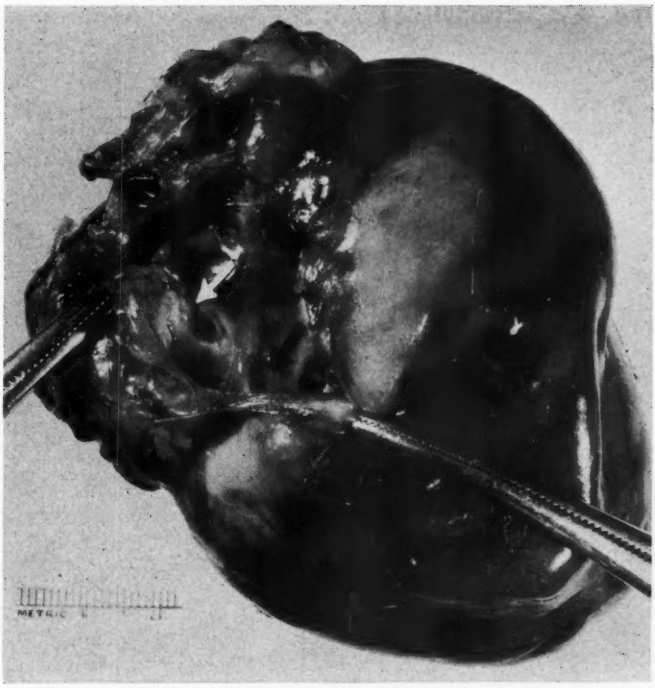

Fig. 3.—The right atrial wall has been excised. The dark arrow points to the coronary sinus, the light arrow points to the defect created. One month after operation.

Fig. 4.—High power view of Fig. 3 showing defect of interatrial septum. One month after operation.

Fig. 5.—The right atrial wall has been removed. The sutured and healed defect of the interatrial septum is shown. There is some distortion of the septum due to the closure of the defect. One month after operation.

Fig. 6.—Showing method of suturing large defect of interatrial septum to left artial wall. The instrument is closed.

in relation to the size of the rings of the clamp. By using larger sized animals, larger than thirty pounds in weight, the results are much better and only occasionally is the animal lost.

By this method which I have used, a portion of the atrial septum, up to 2.5 cm. in diameter, can be completely exposed on its right surface. Defects, or communications with the left atrium, can be made under direct vision of a known and desired size, up to 2.5 cm. in diameter (Figs. 3 and 4). Obviously,

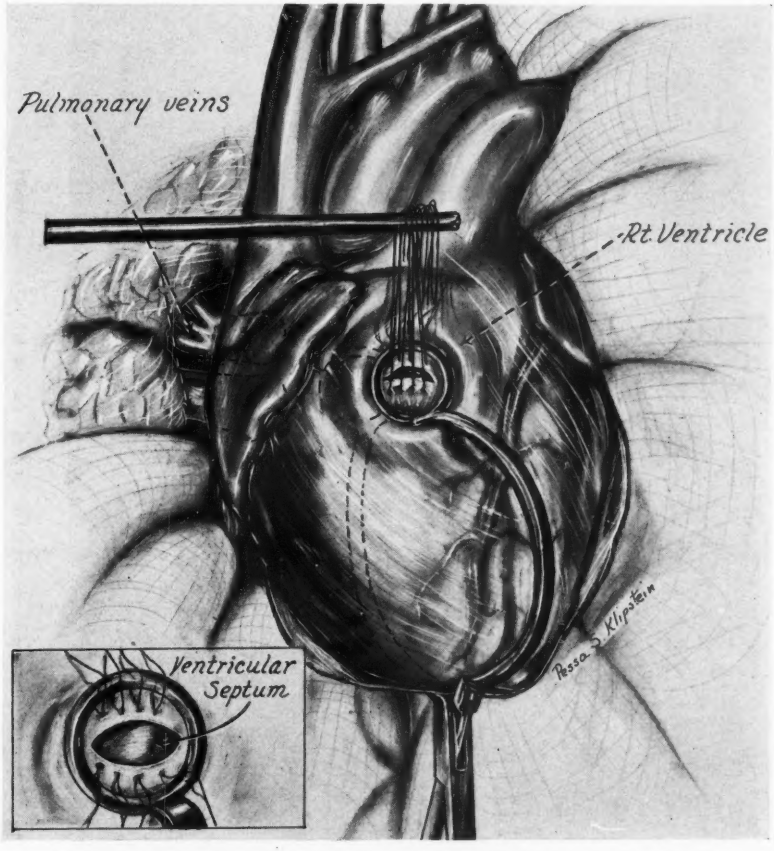

Fig. 7.—Showing instrument applied to ventricles with closure sutures in place.

a defect of 2.5 cm. in the dog's interatrial septum constitutes almost a total excision. The resulting defect can be closed by the use of a continuous silk suture (Fig. 5). In some instances, where the defect created was larger, it was closed by suturing the edge of the defect to the left atrial wall (Fig. 6).

According to Templeton and Gibbon,[7] the superior and inferior venae cavae may be completely occluded for as long as nine minutes and have the animal

Fig. 8.

Fig. 9.

Fig. 8.—The incision in the right ventricular wall is healed. One month after operation.

Fig. 9.—The healed right ventricular incision has been opened. The buried silk sutures are seen in the septum. One month after operation.

survive. While the instrument applied to the atria may decrease the amount of blood reaching the ventricles, there is no visible dilatation of the venae cavae present. After the heart has been totally exposed, a defect in the interatrial septum can be palpated by placing the index fingers on each atrial wall and compressing them against the septum.

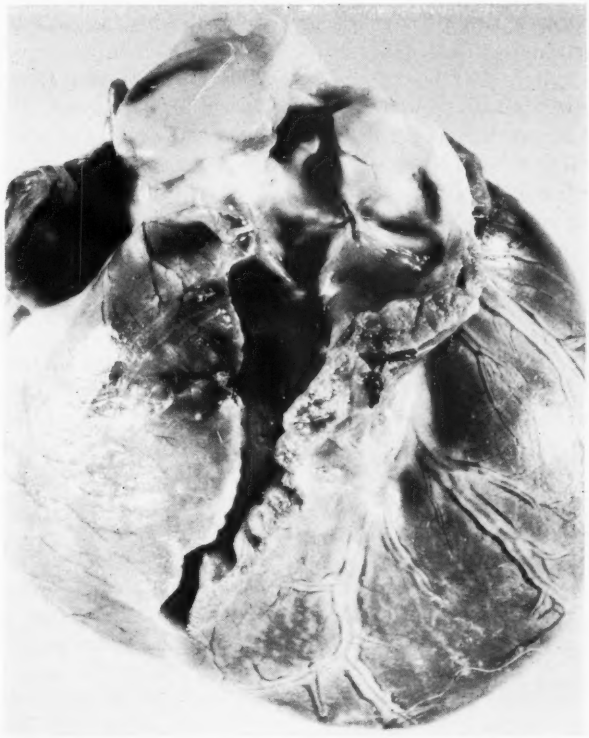

Fig. 10.—A buried silk suture is seen in the pulmonary valve. One month after operation.

EXPOSURE OF INTERVENTRICULAR SEPTUM

In the application of the instrument to the ventricles, the left ventricular or posterior wall is collapsed against the septum, while the anterior or right ventricular wall is compressed against the anterior wall of the septum (Fig. 7). A transverse incision is then made within the ring of the clamp through the right ventricular wall. The septum is exposed immediately beneath the ventricular wall. Inasmuch as the ventricular septum in the dog is composed of thick musculature, similar to the ventricular wall, it is sometimes difficult to know when one has incised all the way through the ventricular wall. After the ventricular septum is exposed, two or three interrupted silk sutures may be placed in the septum and the incision closed (Figs. 8 and 9). Also a defect in the septum may be created under direct vision. It has been possible to expose

the septum high up near the pulmonary valve. In fact, in one instance, it was possible to place a suture in the middle pulmonary valve cusp (Fig. 10). The duration in which the instrument can be kept in place is comparatively short, not over three or four minutes. Some of the difficulty has been in the fact that the clamp may occlude the left coronary artery. Perhaps, by varying the size and shape of the posterior limb of the clamp and with some supplemental method of oxygenation during the procedure, the instrument can be applied for longer periods of time.

Approximately fifty operations have been done. During the early part of the period the mortality rate was approximately fifty per cent. However, with experience and practice, it is now possible to expose either the interatrial or the interventricular septum with only an occasional death of the animal. This is particularly true in dealing with the interatrial septum since the instrument may be released at any time.

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(See discussion on page 672.)

THE CHOICE OF THE SIDE FOR APPROACH IN OPERATIONS FOR PULMONARY STENOSIS

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BLALOCK on Nov. 29, 1944, operated on a 15-month-old blue baby and created an anastomosis between the left subclavian and pulmonary arteries. The operation was successful in increasing the quantity of blood flowing through the infant's lungs and in a short time other children suffering from pulmonary stenosis were given similar surgical treatment. Four years later, he was able to report and analyze the results of over 600 operations.[2] At first, it was thought that the systemic-pulmonary shunt could be safely accomplished with the use of any of the larger vessels in the region of the aortic arch, namely, the two subclavians, the innominate, and the left common carotid arteries. However, the incidence of cerebral damage soon narrowed the choice to the two subclavians and, furthermore, Blalock early expressed a strong preference for one particular subclavian, that which comes off the innominate artery rather than off the aorta itself, because of the more favorable angle formed with the parent vessel after the rotation downward toward the pulmonary artery.

A method of producing the shunt without using any of the arterial branches became available when Potts and his associates[3] devised the aortic clamp which permits the creation of a direct aortic-pulmonary anastomosis without even temporary complete occlusion of the thoracic aorta.

When the surgeon is asked to operate on one of these patients, his pediatric colleagues will inform him of the position of the aortic arch (it is inclined toward the right in a fourth of the cases) and whether or not there is dextrocardia (not rare in this group). He then has to decide whether a Blalock or Potts type of procedure is indicated, and if the former, which side of the chest should be entered. It is not presumed that this communication will give the final answer to these questions, but it will present our personal experience in 50 operations and will show how we have arrived at a simple rule for resolving the problem of the side for operative approach in the individual case.

The fifty operations were carried out on forty-nine patients with pulmonary stenosis or atresia. All of the patients were examined preoperatively by Dr. Robert Ziegler and Dr. Mason Sones of the Division of Pediatric Cardiology. It is to their credit that every patient operated on was found to have a definite deficiency in pulmonary circulation. They have also rendered yeoman service in the matter of postoperative care. Our failures have been due to technical errors in the operating room or grossly unfavorable anatomic situations.

Blalock operations were planned for thirty-five of the fifty patients. With two exceptions, the age range was from 2 to 24 years. Fifteen were over 12 years of age. There were five failures to complete the operation. A girl, aged 15 months, was found to have the pulmonary arterial tree represented only by tiny branches to the upper pulmonary lobes, a condition verified at autopsy.

From the Division of General Surgery of the Henry Ford Hospital.
Read at the Twenty-Ninth Annual Meeting of the American Association for Thoracic Surgery, New Orleans, La., March 29, 30, 31, 1949.

A girl of 20 months showed no vestige of a pulmonary artery at operation and post-mortem examination revealed that life had been maintained by blood which reached the lungs through dilated bronchial arteries. A third patient expired on the operating table after the operation had been discontinued because of spells of bradycardia approaching asystole which occurred every time the right pulmonary artery was manipulated. This was the only death in the operating room.

The other two operations were not completed because the right subclavian artery which arose from the innominate could not be approximated to the pulmonary artery so that an anastomosis could be made. Following are reports of these two cases.

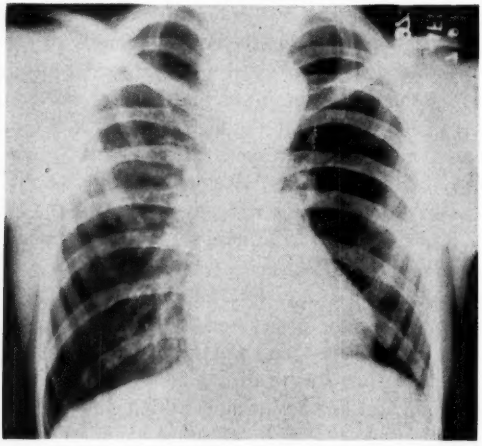

Fig. 1.—Roentgenograms of the chest, Case 2, showing the very high aortic arch. Neither subclavian artery could be approximated to a pulmonary artery.

CASE 1.—T. G. was a moderately cyanotic girl of 11 years, rather tall for her age. The aortic arch was on the left. On Sept. 10, 1946, the right chest was entered through the third interspace anteriorly. A fair sized, but thin pulmonary artery was available. The right subclavian artery was isolated in the superior mediastinum with considerable difficulty due partly to poor exposure through the third interspace incision. It was ligated and divided at as high a level as was practical. It could not be approximated to the pulmonary artery until the carotid artery was divided between ligatures so that the length of the innominate could be added to that of the subclavian. Even then the tension on the structures was such that after the placement of the posterior suture line, a small movement of the mediastinum or perhaps an assistant's hand resulted in a disruption of the suture line. After a futile attempt at end-to-end anastomosis the chest was closed with the following vessels divided between ligatures: right common carotid, right subclavian and right pulmonary arteries. The patient recovered consciousness, but became hemiplegic the next day and expired a week later. It is probable that an approach on the left side would have met with more success. Since that early experience, we have not interfered with the circulation to the brain by ligating the carotid or innominate arteries.

CASE 2.—J. F., a boy aged 13 years, had a left aortic arch. On May 17, 1948, the right subclavian artery was ligated and divided high in the apex of the chest. It could not be approximated to the side of the pulmonary artery. An attempt was made to make

an anastomosis with the proximal end of the divided arterial branch to the upper lobe, but because of tension on the structures a functioning shunt could not be formed. The subclavian artery was ligated near the innominate and the chest was closed. He survived the exploration and five months later he was operated on again. A left subclavian-pulmonary anastomosis had been planned. It was found that the aortic arch was extremely high in the chest, a fact which should have been obvious from a glance at the x-ray picture (Fig. 1). The short length of subclavian artery available on this side was totally inadequate to reach the pulmonary and not even a Potts procedure appeared to be feasible because the arch of the aorta was at least three fingerbreaths away from the pulmonary

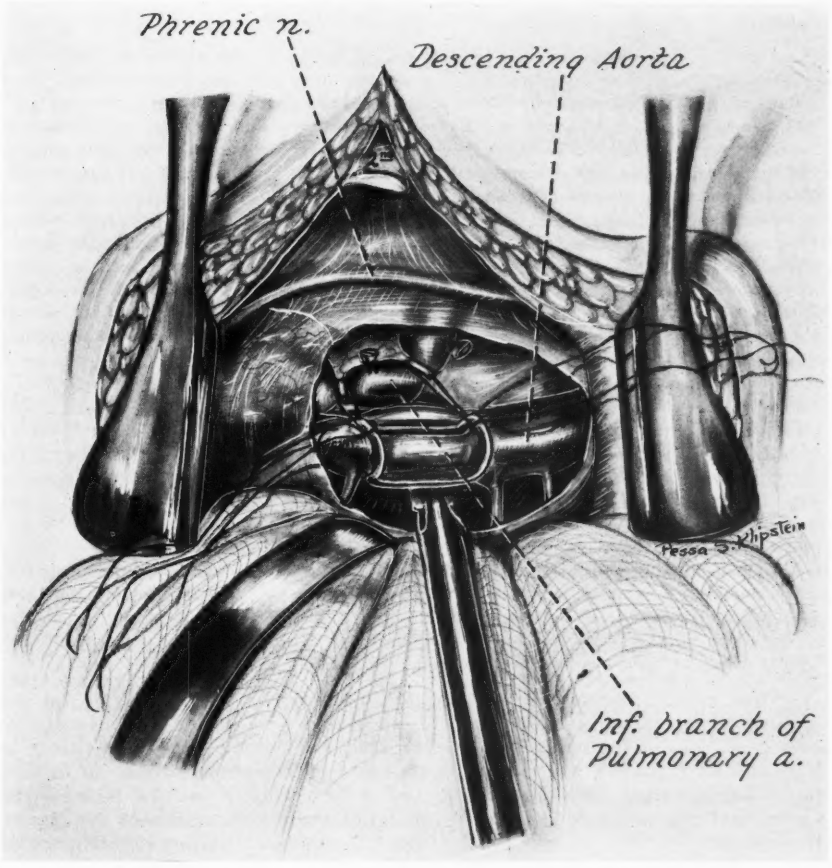

Fig. 2.—Operative procedure eventually carried out in Case 2. An anastomosis was created between the inferior branch of the pulmonary artery and the descending aorta with the aid of a large Potts-Smith clamp.

artery. We considered using the internal mammary artery in some way, but fortunately a better solution was at hand. The descending portion of the pulmonary artery, distal to the origin of the large branch to the upper lobe, was dissected out of the lung substance and with the use of an extra large Potts-Smith clamp which had been made for use in operations for coarctation, a satisfactory direct aortic-pulmonary anastomosis was performed (Fig. 2). It was necessary to ligate and divide the branch to the upper lobe in

order to obtain sufficient exposure of the descending branch. The boy now has a loud ductus murmur in the left lung field and the functional result has been as good as any in the series. It is obvious that an approach from the left in the first instance would have saved him one hazardous operation. The availability of an assortment of Potts-Smith clamps should make it possible to make some sort of a shunt in all cases with a pulmonary artery without dependence on the capricious subclavian artery.

There were two other instances of marked technical difficulty due to the short length of the subclavian artery coming off the innominate. Satisfactorily functioning anastomoses were finally made, but the patients expired on the day of operation due to hemorrhage from points other than the suture lines.

CASE 3.—A. S. was a woman aged 22 years. A left-subclavian pulmonary anastomosis had been made elsewhere on Oct. 28, 1946. Apparently this had not functioned since operation, presumably because of the kinking due to the unfavorable angle. On April 21, 1948, the right chest was opened and the subclavian artery was mobilized and divided as far distally as possible. The pulmonary artery was very thoroughly mobilized and by pulling it up into the mediastinum until it was V-shaped, it was possible to approximate it to the end of the short subclavian, to which marked traction was applied. During the construction of the anastomosis, we were bothered continually with slipping of the bulldog clamp on the subclavian and it was necessary to reapply it four times. Traction on the holding sutures attached to the clamp did not hold the artery steady enough and an assistant was forced to grasp it with a Kelly clamp. Unfortunately during at least a part of the procedure, this clamp became locked over the two jaws of the bulldog clamp. After the completion of the anastomosis, there was no leak in the suture line when the pulmonary constrictors were released, but when the bulldog clamp was removed, there was brisk hemorrhage from a longitudinal slit in the subclavian artery. This injury was obviously where the arterial wall had been fractured by the tightly applied bulldog clamp. The defect was repaired by suture, after which the operation was considered to be a success and the chest was closed. Her color was remarkably improved. During the evening, the blood pressure was observed by means of a cuff applied to the lower extremity, since by this time both subclavians had been ligated. This pressure rose from 220 mm. to 260 mm. of mercury. Still nothing happened until she vomited. She then became pulseless and expired. Autopsy showed a new longitudinal rupture in the subclavian artery, obviously the companion injury to the one which had been repaired at the operation. Assuming that the postoperative hypertension and vomiting were inevitable, the fatal outcome probably could have been prevented by buttressing the injured artery with Gelfoam by the method of Jenkins.[4] There might have been less tension if the distal end of the divided pulmonary artery had been used for the anastomosis.

CASE 4.—M. T. was a 13-year-old girl with a left arch. On April 26, 1948, she was operated on from the right side. The subclavian artery was very short and we anticipated some of the kind of trouble which had been encountered five days before in patient A. S. No branch of the artery was visible and after rather marked traction was put on it to obtain length, a single simple ligature was tied as far distally as possible. With the purpose of saving all available length, the vessel was transected rather close to the ligature. The ligature came away in the operator's hand. There was a brisk flow of blood from the apex of the chest which was controlled by gauze packing. Before blood replacement was complete, there was a period of hypotension (60 mm. mercury systolic) during which time the packing was removed without recurrence of bleeding. Attempts were made to pick up the end of the vessel with a clamp, and one or two sutures were placed blindly in the general area, but it was presumed that the vessel was still insecurely ligated. It was decided that a reasonable procedure would be to pack the neck from below with Gelfoam, close the pleura tightly by suture and proceed with the anastomosis. It was believed that normal blood pressure would be achieved before the chest was closed and thus the hemostasis would receive a physiologic test. A moderately satisfactory anastomosis was formed between the end of the subclavian artery and what was thought to be the main pulmonary

artery. The blood pressure by this time was 100/60 and there was no sign of hemorrhage from the apex of the chest, therefore, the lung was expanded and the incision closed. Several hours after the operation, Dr. Ziegler became alarmed because he could feel a pulse in the right wrist. His fears were well founded, because a short time later the patient expired suddenly and autopsy showed a massive right hemothorax. The subclavian vessel had been cut flush with the common level of origin of the vertebral artery and thyrocervical trunk. A soft thrombus had been blown out by the increase in blood pressure. The examination also revealed that there was early branching of the pulmonary artery and only the superior branch had been exposed and utilized for the deficient anastomosis. In retrospect, the fatal outcome could have been avoided by using a transfixion ligature on the distal end of the cut subclavian even though it meant losing a few millimeters of length, or, after the slipping of the ligature, the open vessel should have been adequately exposed and ligated after splitting the sternum from the second interspace upward.

CASE 5.—Following these two fatalities, the next patient to be operated on was a girl of 13 years, S. T., with a left arch. The right approach was used again. A large vertebral artery came off the subclavian early, and the continuing artery was not of good caliber. An attempt was made to use the divided proximal end of the upper pulmonary branch, but the anastomosis appeared to be carrying a grossly inadequate quantity of blood and it was excised. The suturing for an end-to-side anastomosis was completed twice, using the part of the artery distal to the vertebral branching, but it was obvious that an insufficient shunt had been created. After extreme mobilization of the carotid and pulmonary arteries, we were able to make a large end-to-side anastomosis after sacrificing all of the subclavian artery distal to vertebral. It is a tribute to the anesthetist that his patient recovered consciousness following a long period of anesthesia, and made an uneventful recovery, being completely relieved of her previous incapacity.

It is understandable that after the experiences just related, we were extremely interested to hear the presentation of Holman[5] at the Quebec meeting of the American Association for Thoracic Surgery in June, 1948, in which he stated that the left subclavian artery had been deliberately chosen in preference to the right in twenty-three cases. In his discussion of this paper, Blalock said that he, too, would choose the left subclavian artery if the subject were over 12 years of age or over 5 feet in height. All of the five cases mentioned above come in that category. However, our experience with the right subclavian artery in the borderline group of cases had been so distressing that we decided to follow the suggestion of Holman and use the left subclavian in all cases in which the Blalock procedure was planned, regardless of the age of the patient. In this connection, it will be remembered that there has been unanimous agreement that if there is a right aortic arch, the left approach will be used with satisfaction because one has the advantage of a fairly long subclavian artery with its favorable angle with the innominate as well as the longer and more mobile pulmonary artery.

Thus far, mention has been made of only one of the factors which contributes to the difficulties of a right subclavian-pulmonary anastomosis, namely, the shortness of that subclavian artery. There are other anatomic peculiarities which make the right-sided operation hard. Fig. 3 shows what is seen in the average case after beginning the dissection of the pulmonary artery. Only the superior branch of the artery is visible. After division of the azygos vein and retraction of the vena cava, the main trunk becomes evident, but too often the inferior branch comes off quite proximally, with the result that there is little length of the main trunk available for an end-to-side anastomosis, and the inferior branch tends to prevent the artery from being dislocated upward, a maneuver which is

essential. Even after the vena cava has been mobilized and retracted anteriorly and medially, the systemic vessel to be used is not visible, except occasionally in the extreme apex of the chest. It seems to lie in a separate fascial compartment in the mediastinum and is reached only by sharp dissection through tissues which

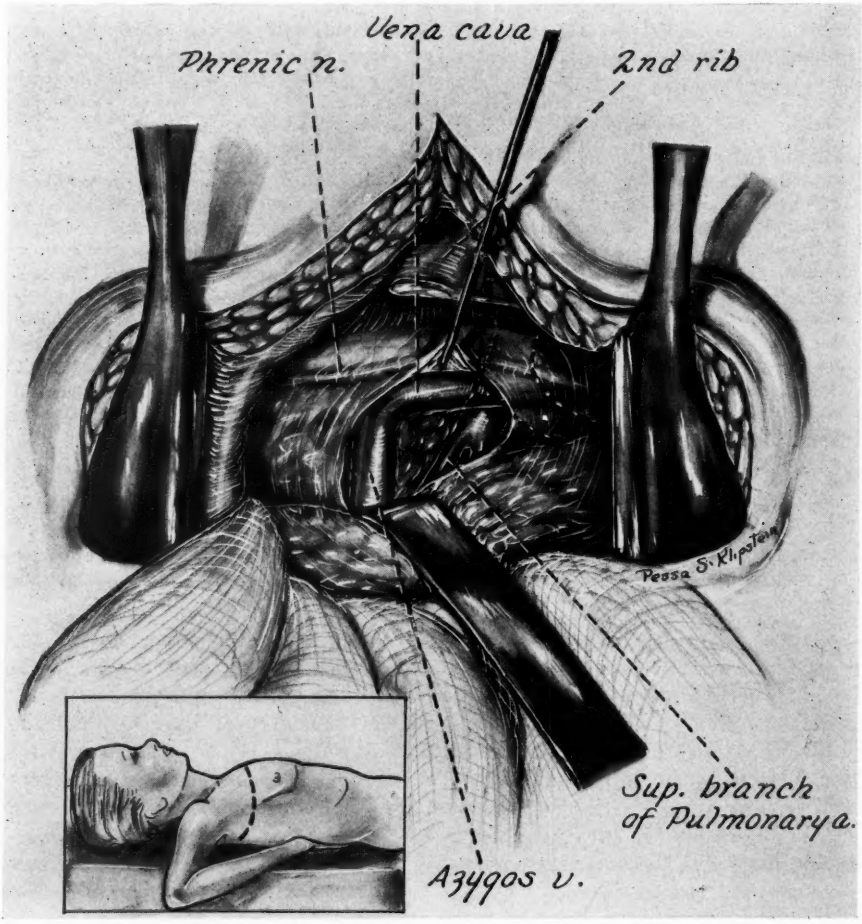

Fig. 3.—Structures seen at the beginning of the dissection to expose the right pulmonary artery. The main trunk of the artery and the inferior branch lying behind the vena cava and right auricle are indicated by dotted lines. The azygos vein must be cut and extensive dissection carried out behind the vena cava to expose the subclavian artery.

may bleed in a troublesome way. A small branch torn off inadvertently is followed by brisk hemorrhage which tends to convert the operative area into a large mediastinal hematoma. The recurrent nerve prevents free mobilization of the vessel before the latter has been ligated and divided.

In contradistinction, on the left side (if the arch is on the left), in almost every case one sees the two structures which are to be joined as soon as the rib

spreaders are applied and the upper lobe of the lung is retracted downward and laterally (Fig. 4). The pulmonary artery and subclavian artery lie just beneath the pleura. When the pleura is cut, it retracts because of its own elasticity, and leaves an assistant's hand free which would be utilized in retracting the vena cava if the incision had been on the right. The recurrent nerve passes back of the aorta itself and neither it nor the vagus are close enough to the subclavian

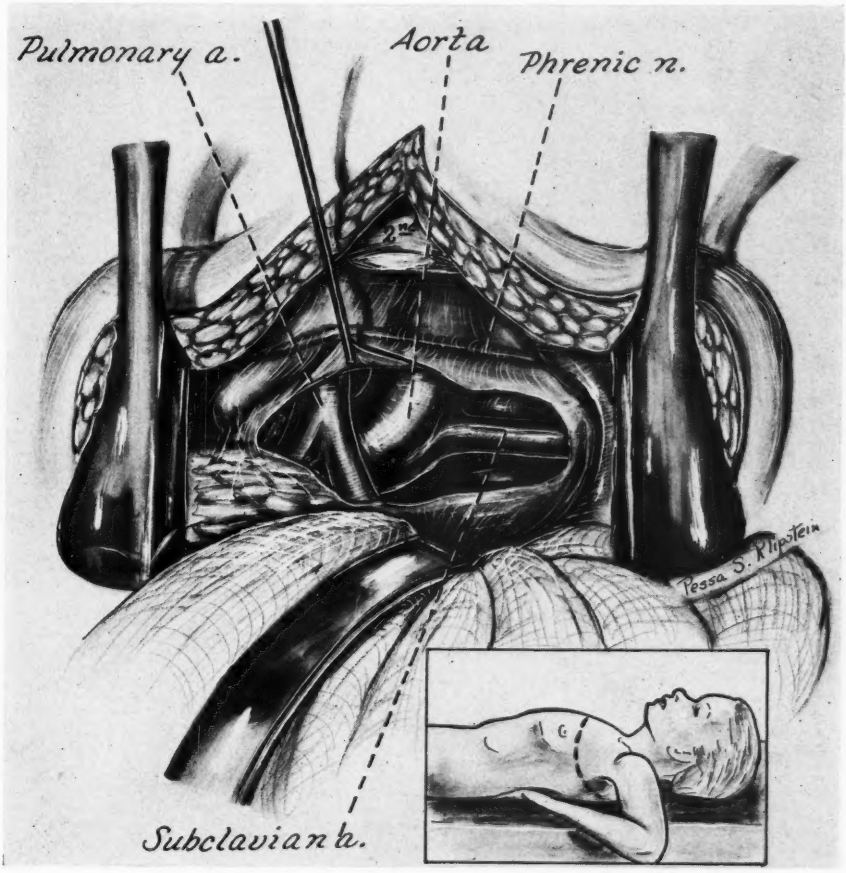

Fig. 4.—Operative field after preliminary dissection on the left side. The structures to be joined are evident with little or no dissection.

artery to be in danger when that vessel is mobilized. A relatively long segment of the main trunk of the pulmonary artery is available for the anastomosis. After mobilization, it can be brought quite high in the chest to meet the systemic vessel (Fig. 5). If the opening in the pulmonary artery is placed far laterally on the vessel, the subclavian artery is not caused to bend so acutely over the aorta, and the length of the pulmonary proximal to the anastomosis is increased.

The one and only disadvantage to the left approach is the fact that a vessel which previously passed upward now passes almost directly downard, so that there is a tendency to kinking at the point of origin and through most or all of its new course it is in contact medially with a relatively unyielding structure, the convexity of the aortic arch. If the danger of compromising the free flow of

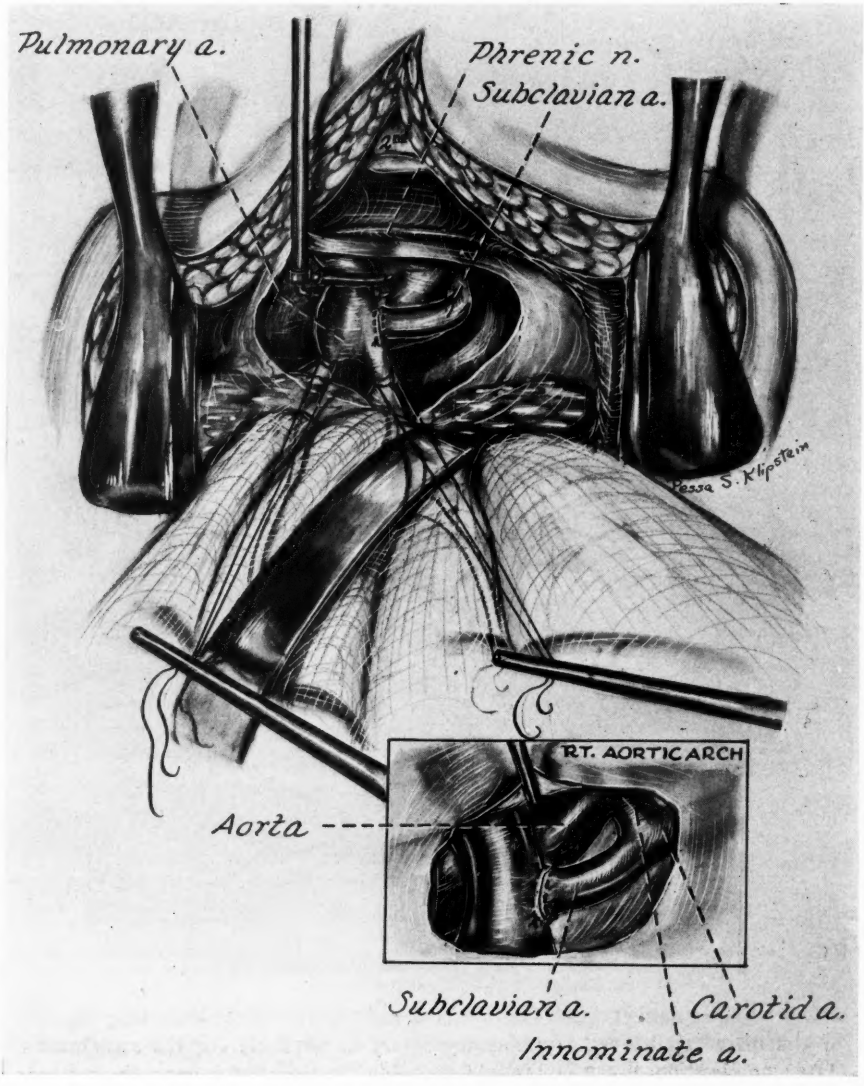

Fig. 5.—End-to-side anastomosis between the left subclavian artery and the pulmonary artery is complete. Inset: favorable angle of subclavian artery with innominate if there is a right arch.

blood through the shunt is considerable, this one disadvantage outweighs all of the advantages. There is some evidence that the danger is more theoretical than real. Holman used the left subclavian twenty-three times. In nineteen of these, he was satisfied with the blood flow following the anastomosis, and in the other four the pulmonary artery was divided proximal to the anastomosis to relieve the angulation, thus producing what was in effect an end-to-end anastomosis. All of these patients were markedly improved. Varco and his associates[6] utilized this vessel in nineteen operations and had eighten good results. Since we decided to use the left subclavian artery, fourteen of eighteen patients have had left arches. The operations were technically easy and all of the anastomoses functioned well immediately. At no time were we tempted to divide the pulmonary artery proximally. Unfortunately for the record, one patient who had a particularly large anastomosis with a good thrill, dramatic improvement in color, and a pleasing change in arterial saturation as recorded by the photoelectric oxyhemograph (Fig. 6), appeared to lose his shunt two days after operation. The loud ductus murmur disappeared. It is possible that a hematoma formed under the pleura which was sutured over the subclavian as it passed over the aorta. As a result of this experience, the pleura in this area will be left open in the future. Probably, the right subclavian will be utilized in a second operation.

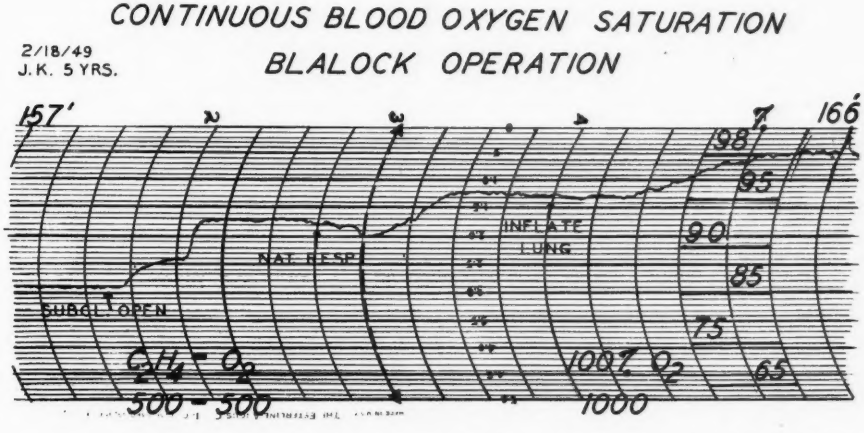

Fig. 6.—Nine minutes of record of photoelectric oxyhemograph showing immediate excellent function of a left subclavian-pulmonary anastomosis. (Record obtained by Dr. Vivien G. Behrman.) The shunt apparently closed two days later.

The only other patient in the series who failed to maintain his improved state following an apparently successful operation was a man of 24 years who died of cerebral embolism on the twelfth postoperative day. The arch was on the right.

The Potts procedure was planned for fifteen patients ranging in age from 5 months to 3 years. Seven babies were under 1 year of age and six of the others were under 2. The operation was technically successful in nine of ten patients

with left arches and in two patients with complete dextrocardia. The right approach was used with complete satisfaction in the latter. However, difficulties were encountered when this approach was used in three patients with right arches and left hearts. In two, the Potts operation had to be abandoned because the aorta and pulmonary artery could not be approximated and unsatisfactory subclavian-pulmonary anastomoses were substituted. In the third, a poor aortic-pulmonary shunt was made with great effort, but the child expired. This was not the experience of Potts himself, who in 1947[7] reported that in twenty-nine patients, there were four with right arches and in each case he had been able to

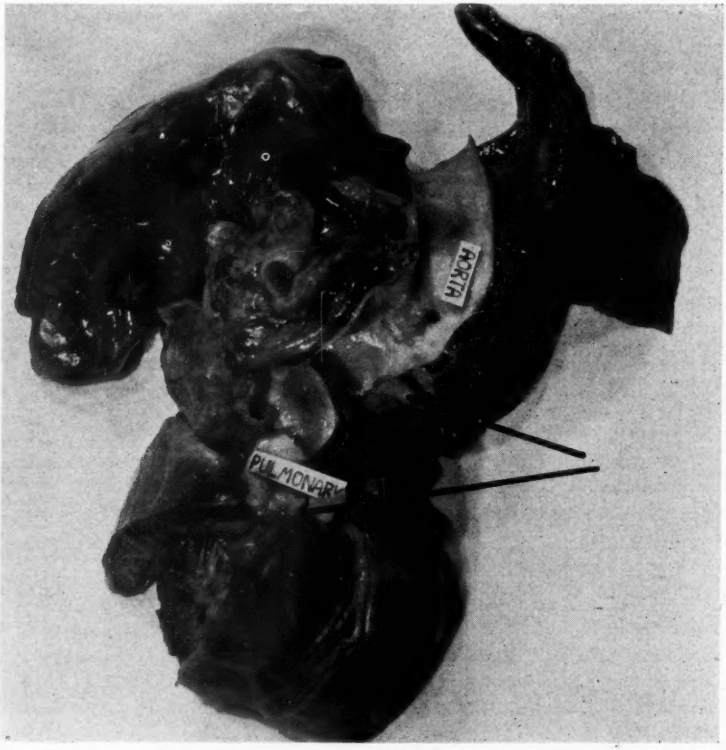

Fig. 7.—Autopsy specimen showing artificial ductus arteriosus (4 mm. in diameter) made by the Potts technique five months before. The ends of the transversely divided pulmonary artery are indicated by arrows, the lower of which points to the stenotic pulmonary valve.

mobilize the pulmonary artery enough to bring the operation to a successful conclusion. The age of these four patients was not stated. In the age group of 3 to 7 years, no doubt the operation is quite feasible but it has been our policy to plan Blalock operations for this group. The ages of the three patients on whom we failed were 5 months, 7 months, and 10 months. It was our feeling that a Blalock operation on the right would have had an equal or better chance of success. The youngest of these children survived the technical failure and may live to have another operation on the left side. Our present position is that if a

child with a right arch and a left heart needs a shunt operation, we will plan a Blalock operation or nothing. This rule was applied to a moribund infant of four months with a right arch, on whom it was thought by the pediatric colleagues that operation might have some slight chance of success. Since he was too small for a Blalock operation and the right arch ruled out the Potts procedure for us, he was not accepted for any type of surgical procedure and expired a few days later. In this connection, it should be remembered that Blalock[2] suggests that if a child under 2 years has a 50 per cent chance of surviving, the operation should be postponed until that age is reached.

It is worth emphasizing again that if a Blalock operation has been planned and a suitable systemic vessel is not available, one has but to ask for the appropriate size of Potts-Smith clamp and proceed with a direct aortic-pulmonary anastomasis. Recently, a 4-year-old girl had a poor systemic vessel because the vertebral artery came off close to the aorta. An excellent aortic-pulmonary shunt was substituted for what would have been an inadequate operation.

There have been two late deaths in children who were improved in the immediate postoperative period following the Potts operation. A child operated on at the age of 6 months as a lifesaving measure lived 5 months and expired in cardiac failure. Autopsy showed a smooth, round artificial ductus arteriosus measuring 4 mm. in diameter (Fig. 7). The pulmonary stenosis was purely valvular. There was no ventricular septal defect, but a large interauricular opening. Children with this type of anomaly do poorly after any type of shunt operation, as compared with those with the more common tetralogy of Fallot. Valvulotomy would be the procedure of choice. Another child operated on at the age of one year was much improved until she died suddenly of an acute systemic infection thought to be meningococcemia. The autopsy showed no evidence of infection about the heart, and the smooth artificial ductus measured 2 by 3 mm.

Finally, a word should be said about the anterior versus the posterior approach for both operations. We have used the posterolateral approach through the fourth interspace without rib transection for children for whom the Potts procedure was planned. With one exception, we have employed the anterior approach through the second interspace for the Blalock operation, cutting the second costal cartilage. The exception deserves special mention. A wide posterolateral incision was made for a left subclavian-pulmonary anastomosis in a mentally defective child of 5 years. The internal mammary, vertebral, thyrocervical trunk and the continuing subclavian artery were ligated separately. Gangrene of the arm resulted and the child expired. Apparently if the subclavian artery is to be ligated in the above manner, it is unwise to cut the muscles of the shoulder girdle and their collateral arteries in order to make a posterolateral incision. In order to choose freely between the Blalock or Potts procedures after the chest is opened, one should enter the chest anteriorly.

SUMMARY

Fifty operations for pulmonary stenosis or atresia have been carried out at the Henry Ford Hospital following diagnostic procedures by Dr. Robert Ziegler and Dr. Mason Sones. There were thirty-one Blalock operations, and fifteen Potts operations; four times no shunt was completed. Anatomic factors which

make the surgical procedures difficult or easy and which influence the end results have been discussed. Technical difficulties during each operation when the right approach was used have caused us to adopt the following simple rule for choosing the side for operative approach: the incision is made on the side of the apex of the heart, regardless of the position of the aortic arch or the age of the patient.

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DISCUSSION ON "A METHOD FOR EXPOSURE OF THE CARDIAC SEPTA" BY DR. F. D. DODRILL,* AND "THE CHOICE OF THE SITE FOR APPROACH IN OPERATIONS FOR PULMONARY STENOSIS" BY DR. CONRAD R. LAM

DR. JOHN C. JONES, Los Angeles.—I would like to emphasize one point, and that is that if, in the case of a small infant, there is doubt about on which side the aorta descends, the approach is best made on the left side. I cite one case to emphasize the fact that the surgeon should not be entirely baffled if he does find that he is on the side on which the aorta is not present even if before the operation he had intended to carry out the Pott's operation. We operated on an infant about three months ago who was 8 weeks old at the time. The child had become cyanotic suddenly at the age of 6 weeks and was brought to the hospital about ten days later, was in oxygen continuously and, of course, was deteriorating rapidly and the clinical study was quite inadequate. In fact we were not certain whether the aorta descended on the right or on the left; the clinical diagnosis was the tetralogy of Fallot. We approached the operation from the left and found the aorta was on the right side. It would have been fatal, of course, to have allowed the child to continue in this way, because without an anastomosis it was unlikely that she would have survived. It was an emergency and the child was in poor condition. By dissecting the carotid and the subclavian arteries, carrying the carotid dissection well up into the neck, we were able to bring the subclavian artery down on the left side and anastomose it to the pulmonary artery. Even though it appeared to be a small subclavian artery, anastomosis was technically feasible; there was an excellent thrill in the pulmonary artery and the child made an uneventful convalescence and went home ten days after operation in excellent condition.

It is three months since operation and while it may be that she will return later on and may need another shunting operation, the point is, I think, that if one is in doubt whether the aorta lies on the left or on the right, one should go in on the left even if the aorta is on the right, rather than chance having a bad angle on the right side with the Potts operation, and to proceed with the Blalock operation by a good dissection going well up into the neck and using the subclavian artery to anastomose to the pulmonary artery. This case convinced me that the Blalock operation is feasible in tiny infants.

*See page 652 for article by Dodrill.

DR. W. J. POTTS, Chicago.—We have come to somewhat similar conclusions for slightly different reasons. I wish to discuss briefly our procedure with right arches in cases of pulmonary stenosis. (Slides.)

In the first twenty-two patients we did aortic pulmonary anastomoses on the right, in patients from 4 months to 17 years of age. In that group we have had two deaths, one from anoxia and another from prompt and complete closure of the anastomosis. We have done subclavian pulmonary anastomosis more recently on eleven patients with right arches with no deaths and satisfactory results. We have made five explorations with two deaths; none of these patients had a pulmonary artery. There were no patients in this group in whom we failed to make an anastomosis if there was a pulmonary artery. One two-year-old child had closure of the anastomotic channel. A satisfactory subclavian pulmonary anastomosis was later done. A total of 37 of 175 patients operated upon for pulmonary stenosis had right aortic arches (21 per cent).

There have been a few interesting variations from the usual procedure. In this case closure of the pulmonary artery in preparation for anastomosis on the right side led to prompt signs of impending death. The pulse dropped and the blood pressure fell. A branch to the upper lobe of the lung was tied off distally and the proximal end was anastomosed to the side of the aorta. The boy made a satisfactory recovery. There have been no signs of change in the lung. This case was previously reported by Dr. Sidney Smith.

A similar situation presented itself in a second patient with a right arch. Closure of the pulmonary artery in this case also led to a severe drop in blood pressure. We used a new type of clamp which occluded a tangential portion of the pulmonary artery and left enough room to do the anastomosis while a fair amount of blood went to the left lung. As you see, we did an over-and-over suture. We did not do an intima-to-intima anastomosis. Recovery was satisfactory.

This is our present policy: If the arch curves to the right we do a subclavian pulmonary anastomosis. If the patient is an infant in whom presumably the subclavian will be too small, the right side is entered and an aortic pulmonary anastomosis done. In all patients with a left aortic arch we routinely do an aortic-pulmonary anastomosis.

DR. SANFORD E. LEEDS, San Francisco.—Since Dr. Lam mentioned the use of the branch of the right pulmonary artery to the right upper lobe, I would like to elaborate on that point. We have employed the right-sided approach in younger patients who have a left aortic arch. (Slides.)

We have had difficulty in some of our cases due to a short right subclavian, short pulmonary artery, or high take-off of the right subclavian from the innominate artery.

It was thought that it might be possible, where there are short vessels, to use the *branch* of the pulmonary artery to the right upper lobe, doing an end-to-end anastomosis between the proximal end of the branch and the right subclavian artery.

This procedure was first tested in dogs by anastomosing the left subclavian artery to the proximal divided end of the left pulmonary artery. The experiments showed that the entire left lung could survive with the pulmonary artery divided and also the heart showed no enlargement or other abnormality from the shunt after observation for several months.

The procedure has now been used with excellent results in four cases of tetralogy of Fallot. It seems advantageous to sacrifice the pulmonary circulation to a portion of the lung in selected cases rather than to use the innominate or carotid artery and run a greatly increased risk of cerebral complications.

An additional purpose for this procedure is when there is an absence of the left pulmonary artery or if there has been a thrombosis of the left pulmonary artery from a previous operation. In these cases the branch of the right upper lobe may be occluded at its origin from the right pulmonary artery by means of a bulldog clamp and the anastomosis may then be carried out without occluding the main right pulmonary artery.

DR. LAM.—There was nothing said in the discussion with which I can disagree, but I cannot miss this opportunity to have the last word in this symposium. I hope that I was able to convey the idea that one of the advantages of the left approach is that one can use Dr. Potts's very clever operation in case one is unable to use the subclavian artery.

PULMONARY RESECTION FOR COCCIDIOIDOMYCOSIS
REPORT OF A CASE

WILSON WEISEL, M.D., AND GEORGE C. OWEN, M.D., WOOD, WIS.

PULMONARY coccidioidomycosis, with residual cavity or nodule formation, occurred frequently among military personnel stationed in endemic areas in the southwest during World War II.[1, 2] Relatively few reports of surgical resection for these lesions have appeared in the literature.[1-4] In many instances, nodular lesions were resected as tumors of undetermined origin.[1] It is proposed here to report a case of cavitary coccidioidomycosis diagnosed prior to surgery and brought to resection because of prolonged hemoptysis and progression of the disease.

CASE REPORT

A 26-year old, white man was admitted to this hospital Dec. 29, 1947. The patient's chief complaint on admission was pain in the right chest, weakness, increasing fatigue, and hemoptysis. The patient dated his illness to June, 1942, at which time he had first noted weakness and right chest pain. In August, 1943, after a year of service in Arizona, a roentgenogram of the chest was taken due to an episode of chills, fever, and right chest pain. A diagnosis was made of pneumonitis, probably due to coccidioidomycosis, and the patient was hospitalized. He remained in service hospitals, presumably because of persistent pulmonary disease, until the time of his discharge from the army in January, 1945. Immediately after his discharge from the service, the patient entered the Veterans Administration Hospital at Dearborn, Mich., where he remained for two weeks until he was discharged. Chest x-ray picture at this time revealed a thin-walled cavity in the right upper lobe. He returned to his former occupation as a molder in a foundry for six months following his discharge from the hospital, but he was unable to carry on his duties in this capacity due to the recurrence of a severe cough with expectoration of a profuse amount of mucopurulent sputum. These symptoms persisted for the next two years. In addition to the cough the patient had experienced recurring episodes of weakness and at times pain in the right anterior chest wall not definitely related to the respiratory movements. In July of 1946, the patient entered Sunshine Sanitarium in Grand Rapids, Mich., for two weeks. At this time examination of the sputum and gastric contents revealed no evidence of tubercle bacilli, and roentgenograms revealed that the cavity had increased in size. Clinical course was unchanged until nine days prior to admission to this hospital when the patient noted an increase in cough with expectoration of blood-streaked sputum, increasing weakness, and night sweats. The patient's expectoration of blood increased until the time of admission, at which time he was having moderately severe hemoptysis daily. This continued during his stay in the hospital and up to the time of his operation.

A review of the family history revealed that the patient's father had died at the age of 52 of pulmonary tuberculosis and one brother among sixteen children had also died of pulmonary tuberculosis.

The patient's occupational history was significant in that he had worked in a foundry as a molder for two years prior to his service with the Armed Forces and had worked at this occupation for six months in 1945.

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Physical examination on admission revealed a well-developed, moderately well-nourished, white man who did not appear acutely ill. The mucous membranes of the nose and pharynx were injected and edematous. The remainder of the head and neck examination was negative. Examination of the chest revealed decreased tactile fremitus in the right scapular area. The percussion note was resonant throughout. The breath sounds over the right base were bronchovesicular in character and fine posttussive râles were heard over the right posterior chest. The blood pressure was 128 systolic over 70 diastolic and the pulse was 88 beats per minute. The heart was normal in size and position and no murumrs were heard. The abdomen was negative to palpation and auscultation. A yellowish white mucous discharge from the penis was noted. The remainder of the physical examination was essentially negative.

A roentgenogram taken at this institution on Jan. 2, 1948, revealed a large, irregular ring lesion in the right upper lung field, 3½ × 7 cm., which was compatible with a thin-walled cavity (Fig. 1). No other pathologic changes were noted. Sinus roentgenograms taken on January 13 revealed no involvement of the paranasal sinuses. Bronchograms performed on Feb. 3, 1948 showed the previously described cavity in the right upper lobe of the lung with surrounding fibrotic changes. No lipiodol was seen in the cavity and no bronchiectasis or other abnormality could be demonstrated.

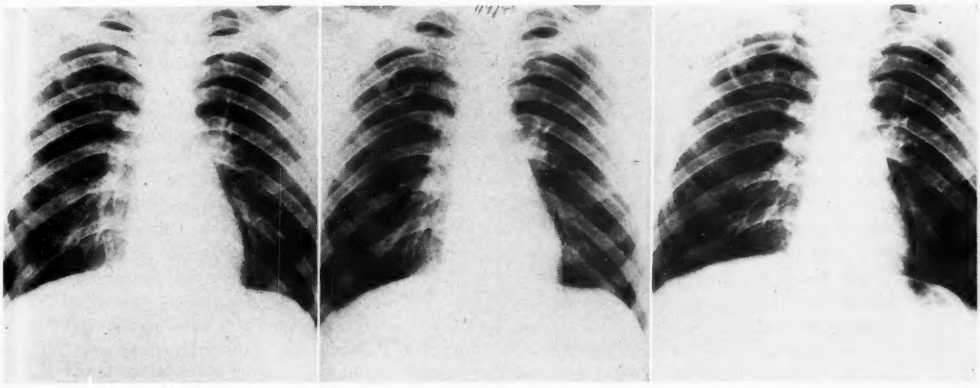

Fig. 1.—Roentgenograms (reading from left to right) taken in 1945, 1946, and 1948, respectively, showing progression of cavitary lesion in right upper lobe.

Clinical examination on admission revealed a white blood count of 16,600; hemoglobin was 12 Gm. per 100 c.c. of blood; the urine was completely negative. Serologic tests for syphilis were negative. A coccidioidin skin test 1:100 was positive. A second strength purified protein derivative was positive. The blood count on January 5 showed white blood cells to 10,800 and hemoglobin was 13.5 Gm. per 100 c.c.; the sedimentation rate was 15 mm. in one hour. Three gastric aspirations, twelve concentrated sputum smears, and ten sputum cultures for acid-fast bacilli were negative. The gram stain of the urethral discharge revealed gram-negative intracellular diplococci. The patient had repeated examinations of the sputum by smear and culture for coccidioides immitis. These were all negative up to the end of January when sputum cultures were found to be positive. His clinical tests on January 29 showed white blood cells to number 11,500 and the hemoglobin was 15 Gm. per 100 c.c. of blood. The prothrombin time on Jan. 26, 1948, was twelve seconds or 100 per cent, and the bleeding time was one minute, and the coagulation time was three minutes.

The patient was treated with intramuscular penicillin following his admission for a period of three days with no clinical change in his condition. He continued to cough and expectorate large quantities of sputum and blood; the quantity varied from one-half pint to approximately one pint daily. The temperature was usually normal with occasional periods

in which it would suddenly rise to 102° F. and return to normal within twenty-four to forty-eight hours.

On Jan. 17, 1948, a bronchoscopic examination was performed which revealed a marked purulent discharge from the right upper lobe bronchus, but no other abnormality of the endobronchial tree was noted.

The steady increase in size of the cavity over the three-year period of x-ray observation, the disabling character of the symptoms of weakness, cough, and copious purulent sputum, and the persistent hemoptysis led to the decision to resect the diseased right upper lobe.

On Feb. 10, 1948 a right thoracotomy was performed following preliminary bronchoscopy. At the time of preliminary bronchoscopy, a pack was placed in the right upper lobe bronchus but due to a rather marked vagovagal reflex and bronchospasm, the pack was removed and the patient was then intubated and he was operated on in the face-down, Trendelenburg position under oxygen pentothal curare anesthesia. A primary incision was made in a curved manner in the right paravertebral space swinging down below the inferior angle of the right scapula. The scapula was retracted and a posterolateral portion of the fourth right rib was removed subperiosteally. The pleural cavity was entered. There were dense adhesions between the upper lobe and the parietal pleura. In these areas, to avoid soiling of the pleura, careful dissection in the endothoracic fascial plane was carried out, leaving the parietal pleura attached to the lung, and the entire right lung was freed from the chest wall. The cavity in the upper lobe was easily felt on palpating the lung and in addition small hard nodules could be felt scattered throughout the upper lobe; this nodulation was also felt in the apex of the lower lobe. The visceral pleura appeared to be thickened and moderately opaque over the entire right lung.

The bronchus was then isolated in the posterior portion of the hilum. There were numerous glands in the mediastinum and these were removed along with the lung tissue. The bronchus was then clamped and cut through proximal to the clamp. The bronchus was closed with a single row of interrupted black silk sutures. The pulmonary artery to the upper lobe was then isolated, ligated, and divided. The superior pulmonary vein was isolated, ligated, and sectioned. There were no distinct fissures between the right upper lobe and the lower lobe nor between the right upper and the middle lobe except at the periphery of the lobes. Therefore, these fissures were developed with excision of portions of the lower and middle lobes to avoid spillage from the upper lobe. The fissures thus created were partially closed with interrupted white cotton sutures which were placed superficially to gain hemostasis and to close any obvious bronchial leaks on the lung surface. The bronchial stump was covered with a mediastinal pleural flap and the entire hilum of the lung at the resected level of the upper lobe was closed by a covering of the mediastinal pleura. The remaining right lung was re-expanded under positive pressure and the chest cavity was closed with moderate suction on the intrapleural space during closure. A drainage tube was placed in the posterior axillary line in the sixth interspace and was attached to a subaqueous drainage bottle. The chest wound was closed in layers using interrupted cotton sutures for the chest wall and black silk sutures for the skin. Penicillin 200,000 units in 5 c.c. of saline were left in the pleural space. The patient's postoperative condition was satisfactory.

PATHOLOGIC SPECIMEN

Gross Description.—The specimen consisted of a right upper lobe of the lung. The pleura was dull and covered with fibrinous shreds. In the upper one-third, there was a bulge to the surface. On section into this area, a cavity was found, which after fixation, measured 3.5 × 2.0 cm. (Fig. 2). The wall of the cavity consisted of a layer of white, fibrous tissue, averaging 5 mm. in thickness. The inner surface was granular and somewhat velvety appearing and was grayish brown in color. Within the cavity and coating the wall, there were many crumbly, yellow patches resembling sulphur particles. Smears and cultures were made of these particles and from the wall of the cavity. The surrounding lung tissue appeared to be moderately indurated. There were many small nodules, each measuring approximately 3 to 5 mm., which surrounded the cavity particularly at the lower portion. The entire lung had a slightly increased consistency, this being more marked in the vicinity of the cavity.

Microscopic Description.—The cavity was lined by a thin layer of necrotic cells and polymorphonuclear leucocytes. There were areas, however, in which no lining was apparent. Both within the cavity wall and deep in the tissue there were foci of epithelioid cells. Some of these cells were also multinucleated giant cells resembling Langhans' giant cells. There was considerable destruction of lung tissue and replacement by fibrous tissue and foci of lymph follicles. The bronchi were often filled with polymorphonuclear cells. In none of the sections examined were spherules found.

Direct smears of the granules lining the cavity revealed mycelia and hyphae consistent with those obtained from cultures of *Coccidioides immitis.*

Cultures of this material yielded characteristic colonies of *Coccidioides immitis.* These were inspected and confirmed by Dr. C. W. Emmons, National Institute of Health, and Dr. N. F. Conant of Duke University.

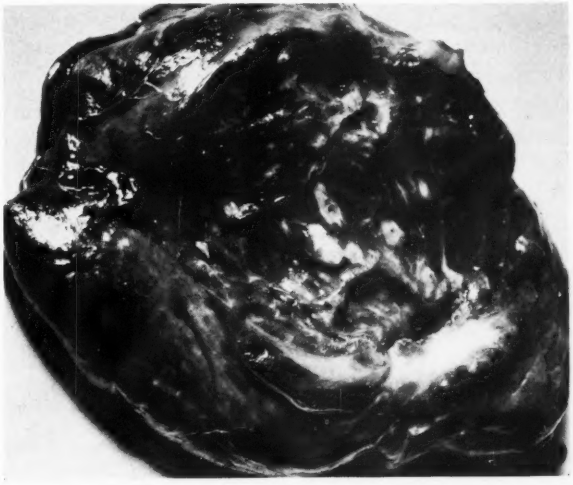

Fig. 2.—Gross specimen demonstrating cavity in cut section of right upper lobe.

Inoculation of culture material into guinea pigs resulted in a granulomatous lesion containing typical spherules of *Coccidioides immitis.*

The patient's postoperative course was uneventful and he was ambulatory on the day of surgery. On the second postoperative day the temperature rose to 100° F. and returned to normal where it stayed during his convalescence. There was a drainage of approximately 600 c.c. of serosanguineous, clear fluid from the chest in the first two postoperative days, after which time the tube stopped draining and fluctuating despite irrigation. The drainage tube was removed on the third postoperative day and no further aspirations were required.

The clinical examinations during the postoperative period were not significant except for a fall in the serum protein. On Feb. 11, 1948, the first postoperative day, the serum protein was normal at 6.4 Gm. per 100 c.c., consisting of 3.6 Gm. of albumin and 2.8 Gm. of globulin. The serum protein fell on Feb. 14, 1948, to 5.3 Gm. per 100 c.c. (3.3 Gm. of albumin and 2.0 Gm. of globulin), and remained at this level for the next three weeks when it gradually returned to normal.

The patient was well enough to return to his home on the ninth postoperative day. He returned to the hospital for postoperative re-evaluation on the first of March, 1948. He has had no complaints referable to the chest and no further expectoration of sputum or blood.

The postoperative roentgenograms of the chest showed an immediate satisfactory aeration of the residual portion of the right lung. On Feb. 11, 1948, the x-ray picture re-

vealed satisfactory aeration of the residual lobes of the right lung with an estimated 20 per cent pneumothorax remaining in the upper portion of the chest. The remaining lung was very slow to fill the upper portion of the chest and at the time of his discharge from the hospital, this was not completely filled. However, there was no evidence of fluid nor of any increased reaction in the pleural space. The last roentgenogram of the chest taken on March 10, 1948, revealed the changes in the right chest incidental to the right upper lobectomy with partial resection of the fourth right rib. The residual right lung had expanded to a level with the second right rib posteriorly with a space between the lung and the upper chest wall. There was also some residual lipiodol in both lower lung fields. Otherwise the chest examination was negative.

A postoperative coccidioidin skin test was negative in twenty-four and forty-eight hours. Three gastric cultures for acid-fast bacilli, which were taken following the patient's operation, were also reported as negative. The other clinical studies on this patient, including the blood and the urine were all within normal limits. The patient was, accordingly, discharged from the hospital to return to his home on March 15, 1948.

COMMENT

Of interest in this patient was the persistence and progression of the cavity five years after the onset of the disease. In addition, the apparent presence of cultures of the fungus growing on the wall of the cavity, with mycelia and hyphae present, is most unusual. In the commonly present spherule form, the disease is said to be noncontagious. However, the finding of mycelial forms in this patient, as in the one preceding case in which this finding was recorded,[5] raises the question of the infectiousness of the disease in patients with long standing, progressive cavities due to coccidioidomycosis, and further justifies surgical extirpation of the disease.

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CARCINOMA OF THE LUNG

A Follow-Up on Sixty-Seven Patients Subjected to Pneumonectomy

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SINCE 1936, we have seen, in association with the Jackson Clinic, 429 patients who have been proved to have carcinoma of the lung. We have purposely limited this study to those cases preceding November, 1947, so that a six months' follow-up could be obtained on even the last case analyzed. Patients who have been seen since that time have not been included.

Of this group of 429 cases, 149, or 34.7 per cent, were considered as possibly operable. Of the 149 patients explored, 67, or 15.6 per cent, of the total were subjected to pneumonectomy, which was routinely performed if there was any hope of cure. The general condition or the age of the patient influenced us only slightly in choosing these patients for operation. Therefore, in certain cases, marked risks were taken in an effort to salvage a possible cure.

It is not the purpose of this paper to consider diagnosis or details of operability, but it seems important at least to state that several patients operated upon did not show x-ray findings suggesting tumor, but the diagnoses were made by other methods, especially bronchoscopy, and exploration was considered worth while if there was no definite evidence of widespread metastasis. In this report we are concerning ourselves chiefly with the 67 pneumonectomized patients, since we believe that the most important consideration is the final salvage.

We have been impressed by the difficulty of making a gross diagnosis at the operating table and have attempted to make a positive diagnosis preceding operation whenever possible. Diagnostic measures have included bronchoscopy, needle biopsy, and, recently, cytologic study of bronchial secretions. Over 90 per cent of our patients have been taken to the operating room with a positive diagnosis. We do not believe much time should be wasted in making this diagnosis, and we rarely study a patient more than two weeks before surgery.

Of the 67 patients submitted to pneumonectomy, certain interesting statistical data have been gathered. The oldest patient in this group was 66 years of age and the youngest 36; the average age was 54 years. We have seen patients much older and much younger than these, but none in our group has been operable. One 27-year-old patient was treated by lobectomy a couple of years before we performed our first pneumonectomy in 1938. He rapidly developed a local recurrence, which we suspect was present in the lymph nodes at the time of the original lobectomy. We have generally avoided lobectomy as a treatment for carcinoma of the lung, although the relatively low mortality figures of lobectomy are certainly intriguing and have not been matched by any series of pneumonectomies.

Of the 67 pneumonectomized patients, 18 or 27 per cent, died in the hospital. Nine died of cardiac complications; the average time was 5.5 days after operation. Two died on the operating table. One died of a proved pulmonary

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embolus within twenty-four hours of operation. One died of what was suspected of being a procaine reaction three days after operation.

Five died of infection. Since 1942, however, when we first started using penicillin, we have lost only one patient from infection, and almost invariably our mortality is due to cardiac complications. Of the remaining 49 patients, 27, or 40.2 per cent of the 67, have died since leaving the hospital. Twenty-two died of metastasis or from extension of the primary lesion in an average time of 11.4 months. Two have died of subsequent carcinoma elsewhere which apparently had no relation to the pulmonary growth. One died of carcinoma of the stomach five months after the pneumonectomy; the second died of adrenal carcinoma twenty-four months after pneumonectomy. In both of these cases we must at least suspect that the tumor of the lung was secondary to the other tumors from which the patients died, but we have no definite proof of this and in each instance the type of tumor was different. Three died of other causes: one of coronary thrombosis ninety-five months after operation; one of diabetic coma twelve months after pneumonectomy; and one of undetermined cause forty-one months after pneumonectomy.

The next group we consider to be the most important. Still living are 22 patients, or 32.8 per cent of the original 67. Twenty are known to be perfectly well, and although this is 30 per cent of our pneumonectomized patients, it is only 4.7 per cent of the 429 originally seen. Of the two patients who are known to be not entirely well at the present time, one is suspected of having metastatis eleven months after pneumonectomy, although this has not been proved. One is still living, forty-nine months after pneumonectomy, although she has a carcinoma of the ovary which has metastasized retroperitoneally. She is now being treated for this carcinoma of the ovary, which is thought to have no relation to the carcinoma of the lung. Of the 20 patients who are known to be living and well, 16 are working regularly.

Of the 22 surviving patients, 11 have been followed from six months to two years and 11 have been followed for periods of over two years. Our oldest living patient has been followed for ninety-seven months and is perfectly well. He has undergone two subsequent operations for other complaints since his original pneumonectomy, and has stood them well. Of the 15 patients who have survived for as long as two years, 11 are still living. Of the 49 patients who survived hospital stay, 15 had gross mediastinal lymph node metastasis. Thirty-four, therefore, had no gross or microscopic mediastinal lymph node metastasis; 26 per cent of those with lymph node metastasis are still living and 53 per cent of those without lymph node metastasis are living.

Another interesting statistical feature concerning the number of patients who have survived over three years, 8 in number in our series, is that half had lymph node metastasis and half did not. So it seems that if lymph node metastasis is present, the patient will either die in a relatively short period of time or will have as much chance to survive as one without lymph node metastasis.

Preoperative preparation is worthy of mention, although we do not intend to discuss it here in detail. It should include a thorough examination of the patient to exclude distant metastasis, which would contraindicate operation, and to evaluate any complication which might influence morbidity and mortality.

X-ray examination of the chest is, of course, essential. This must include fluoroscopic examination of the diaphragm because we have found that, in the presence of tumor, phrenic-nerve paralysis indicates mediastinal invasion.

In the past few years, we have eliminated routine skeletal survey for metastasis because it has seemed to us that skeletal metastases from carcinoma of the lung are almost invariably painful and thereby make their presence suspected. Thus skeletal survey seems indicated only in those patients with so-called bone pain.

Cardiac survey, including electrocardiogram, is essential. We have recently been including circulation time and an overload test which so far have seemed to be a helpful indication of cardiac reserve. The overload test is done by introducing 10 c.c. of saline per pound of body weight into the patient's venous circulation in thirty minutes. Venous pressures and circulation time are taken before and after introduction of the fluid. If the patient develops any untoward symptoms, such as shortness of breath or cyanosis, during the introduction of the fluid, it is immediately stopped.

Bronchoscopy is routinely utilized in an attempt to obtain adequate biopsy and also to determine the exact location of the lesion. Bacteriology of the sputum and bronchial secretions is routinely checked. We have noted that tuberculosis and carcinoma occasionally appear together. Also, routine cultures and susceptibility tests have aided us in choosing antibiotic therapy, which is employed routinely. We consider 200,000 units of penicillin daily for five to seven days before operation, in divided doses, as usually adequate. We have utilized streptomycin when bacteriologic determination indicates it. Recently, we have routinely been employing aerosol inhalations three days before surgery. Repeat bronchoscopy is employed when secretions are excessive or when there is definite bronchial block which might be benefited by bronchoscopy. We have routinely inserted 100,000 units of penicillin and 1 Gm. of streptomycin into the thorax at the time of operation. We have generally utilized approximately 3 Gm. of sulfanilamide powder in the pleural space, but this has recently been discontinued.

Postoperative care has been directed mainly toward symptomatic treatment. In general, we have utilized oxygen for at least twenty-four hours and often longer. We have introduced penicillin and streptomycin into the thorax whenever aspiration for pressure readings was necessary. We have employed low-fluid intake for the first week after operation. We believe that ambulation in patients who have had pneumonectomy should not be hurried. Mild exercise in bed and frequent change in position are encouraged. Undue effort might well throw these patients into cardiac failure, should failure be impending. When patients are permitted out of bed following pneumonectomy, we keep motion as passive as possible.

The drug that has been most helpful to us in treating cardiac failure or impending failure has been digitalis. We have been fearful of using it routinely, but have employed it in adequate dosage when the patient's pulse becomes unduly rapid or when any symptoms suggesting failure appear. If any measures have aided our treatment of impending failure, they have been limitation of fluids and the judicious use of digitalis.

Operative technique has not varied tremendously in the past few years. We generally make our approach through the third interspace anteriorly, since anesthesia is more easily maintained and the mediastinum seems quite accessible from this approach. We routinely ligate the pulmonary artery before the veins are ligated. We generally dissect out the individual vessels before ligating any of them, so that we may perform our operation in stages if the patient's condition seems to warrant it. All vessels are transfixed as well as ligated. At present, we have no definite opinion about bronchial closure. We know of no superior method. If possible, we prefer to pleuralize the bronchial stump.

During the past two years, we have routinely left a small catheter in the thorax for several days, so that changes in pressure can be readily remedied and antibiotics introduced daily. We have done thoracoplasty later only on those patients who developed empyema following surgery. Thoracoplasty then is utilized after the patient has entirely recovered from the pneumonectomy and subsequent postoperative infection, usually in about six weeks to two months. We have not found that these few patients had more pulmonary reserve or better cardiac function than those in whom thoracoplasty was not used.

The extent of our operative procedure has, incidentally, been somewhat variable. We have not hesitated to take out a portion of chest wall when it seemed necessary because of the extent of the tumor; one patient who is living and well thirty-one months after pneumonectomy had a portion of five ribs resected. We have taken out portions of pericardium and, on one occasion, went slightly across the carina in an attempt to remove all obvious tumor. We do not consider any risk too great to take if there is a chance of cure.

COMMENT

It is very difficult to evaluate statistics which have been obtained on such a variable group of cases. It seems very discouraging when one realizes that the salvage rate on 429 patients originally seen is only about 4.7 per cent. It is also somewhat discouraging when we realize that only 149 of these original patients were even subjected to surgery. Of the group who were not operated upon, many patients had very obvious contraindications to surgery when first seen. We have not and do not intend to censor physicians for sending us obviously inoperable cases for evaluation; these patients have been given at least the benefit of careful evaluation, and occasionally palliation has been afforded them by x-ray therapy. We are much more interested in stressing early diagnosis, which will be the most important factor in improving our salvage rate. It is at least hopeful that we have been able to salvage the occasional case.

Certainly the figures that have been accumulated compare favorably with the treatment of carcinoma of the stomach. It is also difficult to evaluate mortality. Our mortality from infection has been largely eliminated, and since 1942 the over-all figures have been reduced chiefly by the use of antibiotics. Our present mortality rate is approximately 20 per cent. Mortality apparently must still depend on the condition of the patient who is being operated on. This mortality is largely due to cardiac failure. We must, therefore, improve our methods of handling this complication. During one period we had fifteen consecutive pneumonectomies without any infection and without mortality.

We have not been able to find any particular reason for this unusual run of what we must consider good luck, and I believe that we will have to attribute it to the fact that we were operating on patients who were better risks than usual.

If we cannot reduce the mortality of pneumonectomy, we must consider lobectomy in some patients who have peripheral lesions. Pneumonectomy is certainly ideal since it affords adequate hilar dissection, but the figures of Neuhof are intriguing, and in our own cases we found only eighteen out of sixty-seven who had hilar lymph node involvement, and this lymph node involvement could have been almost universally predicted because of the location of the lesion. In the light of these reports, it would seem that we must either lower the mortality of pneumonectomy or strongly consider lobectomy in certain peripherally located lesions. The ideal operation is assuredly pneumonectomy.

SUMMARY

Sixty-seven pneumonectomies which have been followed for a period of from six to ninety-nine months have been discussed. The salvage is definite though small, 32.8 per cent. Careful evaluation of the patient preceding surgery is very important. Early diagnosis should considerably improve the operability rate. The most important condition producing postoperative mortality is cardiac failure, infection having been largely eliminated by antibiotic therapy and careful technique. The operative mortality of pneumonectomy must be reduced or lobectomy must seriously be considered in certain peripheral lesions. Twenty patients are living and well for six months to ninety-nine months following pneumonectomy and two others have died of unrelated causes.

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SURGICAL TREATMENT OF CONGENITAL CYSTIC DISEASE OF THE LUNG WITH A REPORT OF TWO CASES

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A DECADE ago, congenital cystic disease of the lung had a formidable prognosis. In a review up to 1935, Schenck and Stein[28] stated that although adults might live for many years with pulmonary cysts, the condition in children and infants carried the gravest outlook and early death was frequent. In an analysis of fifty-one reported cases in infants and children from 1925 to 1935, thirty-five of the patients, or 69 per cent, were dead. Schenck and Stein concluded, "No specific treatment can be offered. Many cases present a surgical problem and future thoracic surgery in infants and children must meet the challenge." Chemotherapeutic agents have altered the prognosis, but the disease and its various complications remain in the realm of thoracic surgery.

In 1943, seven years after the review by Schenck and Stein, Fischer and associates[9] reported a successful lobectomy for congenital cystic disease of the lung in a 4-week-old infant and stated they were unable to find by "close study of the literature" any previously reported successful cases of lobectomy in so young a patient. Gross,[4] in 1946, reported a successful pneumonectomy for pulmonary cysts in a 3-week-old infant. There are few other reports of excisional surgery for this disease in infants. Smith,[13] in 1942, reported a successful lobectomy by Churchill in a 19-month-old infant. He stated, "It is believed that competent surgery offers the best opportunity for cure when the disease is of clinical importance, when discovered early, when localized . . . and when, in certain cases, sufficient time has elapsed that the natural restoration of function seems unlikely."

The present paper is concerned with a report of two cases of congenital cystic disease of the lung which had successful extirpative surgery. One was an infant of 11 weeks who underwent a lobectomy. The other was a boy of 4 years, upon whom a total pneumonectomy was performed. Because of the small number of patients successfully operated upon reported among infants and children, the present two cases are considered statistically worthy of report.

CASE REPORTS

CASE 1.—A white baby boy, J. P., was born on March 25, 1947, of a normal primigravida in the thirty-fourth week of gestation at the Methodist Hospital, Brooklyn. Birth weight was 4 pounds 13 ounces. On the third day of life, the baby became cyanotic after a gavage feeding. X-ray examination revealed what was believed at the time to be an atelectatic right upper lung (Fig. 1). For the next three days, the infant exhibited episodes of cyanosis and coughed up blood-tinged, mucinous material. During this period, he was supported by oxygen, parenteral fluids, antibiotics, and incubator care. Recovery was progressive, and, as the "atelectatic" process of the right upper lung resolved, it became

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apparent that cystic cavitation replaced the lung tissue in this area. He was discharged from the hospital at 5 weeks of age, weighing six pounds, and in good health.

Three weeks later, the patient was readmitted with marked respiratory distress and signs suggesting a tracheobronchitis and consolidation of the right upper lobe. Roentgenogram showed a reaccumulation of fluid in the previously described cavernous area, with surrounding inflammation. Resolution with residual cystic loculation occurred by the twelfth day (Figs. 2, 3). The pediatrician (S. E. P.) requested a consultation, and it was decided that surgery offered the best hope for an ultimate, favorable prognosis.

Operative Procedure.—June 11, 1947, the pleural cavity was entered through the right second anterior intercostal space by the senior author, at the Methodist Hospital. The

Fig. 1.

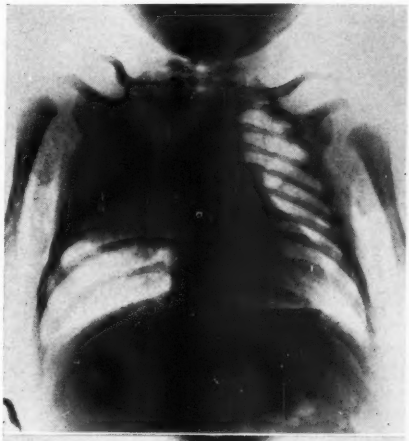

Fig. 2.

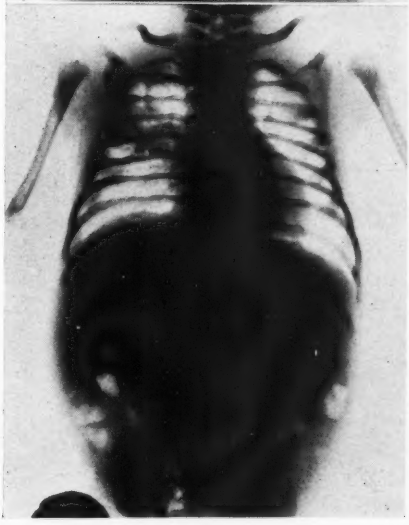

Fig. 1 (Case 1).—First x-ray film from which diagnosis of atelectasis was made.
Fig. 2 (Case 1).—Preoperative roentgenogram showing cystic disease in right upper pulmonary field.

right upper lobe was found to be the site of extensive cystic disease with evidence of recent pneumonitis. An interesting finding was the presence of an extrapulmonary cyst between the upper and middle lobes. It was enucleated separately. A right upper lobectomy was performed; the lobe bronchus was too small and friable to close in the usual manner and it was closed with simple transfixion ligation of fine silk, after individual ligation of the vessels. The middle and lower lobes appeared normal. The chest wall was closed anatomically and intercostal underwater drainage instituted. The remaining lung tissue was seen to obliterate the pleural space and the tube was removed on the second postoperative day. The hospital course was uneventful and the infant was discharged on the eighth postoperative day, weighing eight pounds.

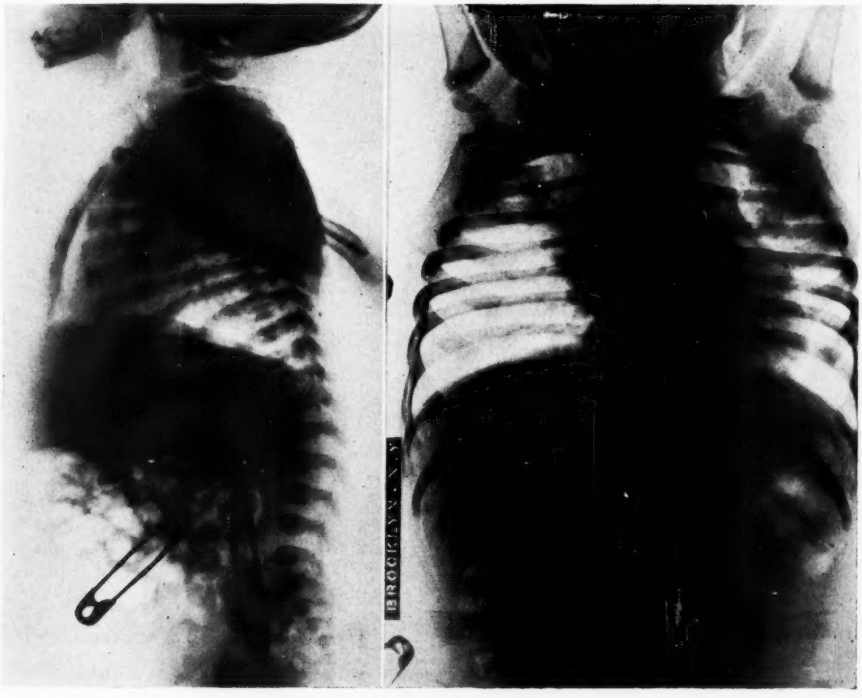

Fig. 3. Fig. 4.

Fig. 3 (Case 1).—Lateral view taken preoperatively.
Fig. 4 (Case 1).—Chest film taken eight months postoperatively.

Microscopically, the cystic structures were seen to be composed of fibous tissue lined with columnar ciliated epithelium characteristic of bronchial mucosa. The surrounding pulmonary tissue was atelectatic and the site of pneumonitis.

On follow-up, sixteen months later (November, 1948), the infant was in good health and weighed 28 pounds. A check-up chest film revealed normal findings (Fig. 4).

CASE 2.—A boy, R. K., was admitted to Peck Memorial Hospital, Brooklyn, for the first time on March 4, 1946, at the age of 2½ years. The chief complaint was cough and crampy abdominal pain for five days, marked by a temperature of 105° F.

Past history revealed an uncomplicated birth. At the age of 23 months, on Aug. 31, 1945, the child suffered an electric shock. He was rendered unconscious and was hospitalized

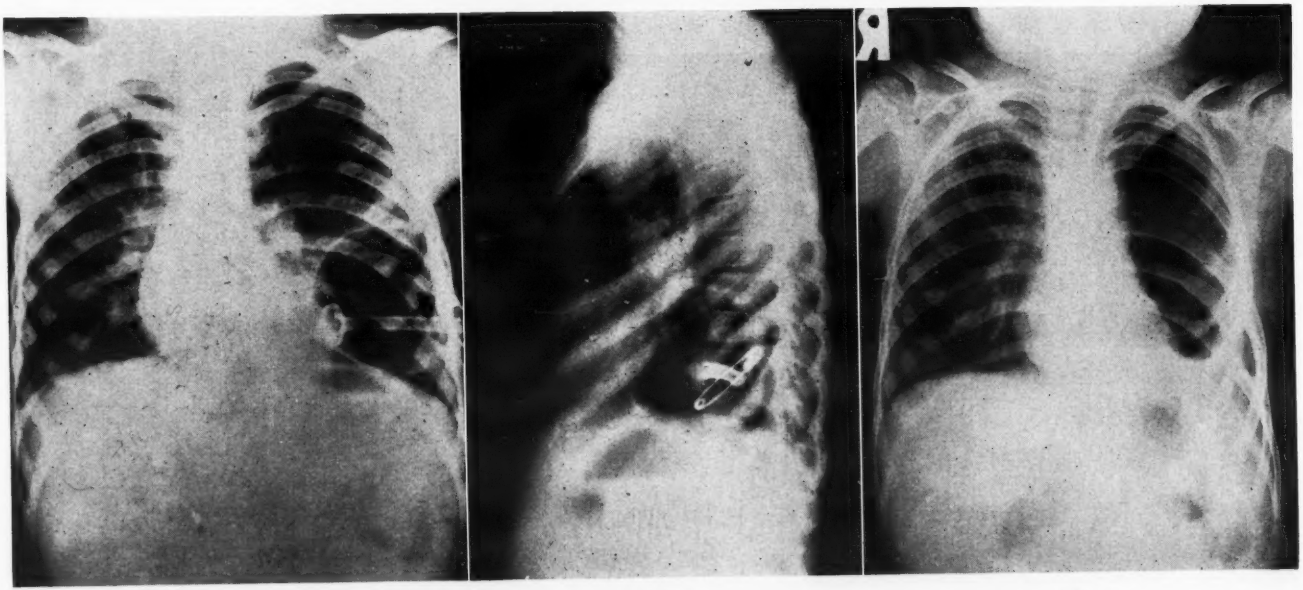

Fig. 5. Fig. 6. Fig. 7.

Fig. 5 (Case 2).—Prepneumonectomy roentgenogram showing catheter within large cyst of left lower lobe. Upper lobe cysts do not show well.

Fig. 6 (Case 2).—Lateral view taken before definitive surgery. The cystic disease of upper lobe is better visualized here.

Fig. 7 (Case 2).—Postoperative x-ray film showing absence of left lung and mediastinum in midline.

for one day. He was discharged with a diagnosis of electric shock and burns. At this time, no abnormality was noted relative to the lung and, unfortunately, no chest film was taken.

For a month prior to the 1946 Peck Hospital admission, the child had exhibited easy fatigability. He did not elect to climb stairs and his play tolerance had become short.

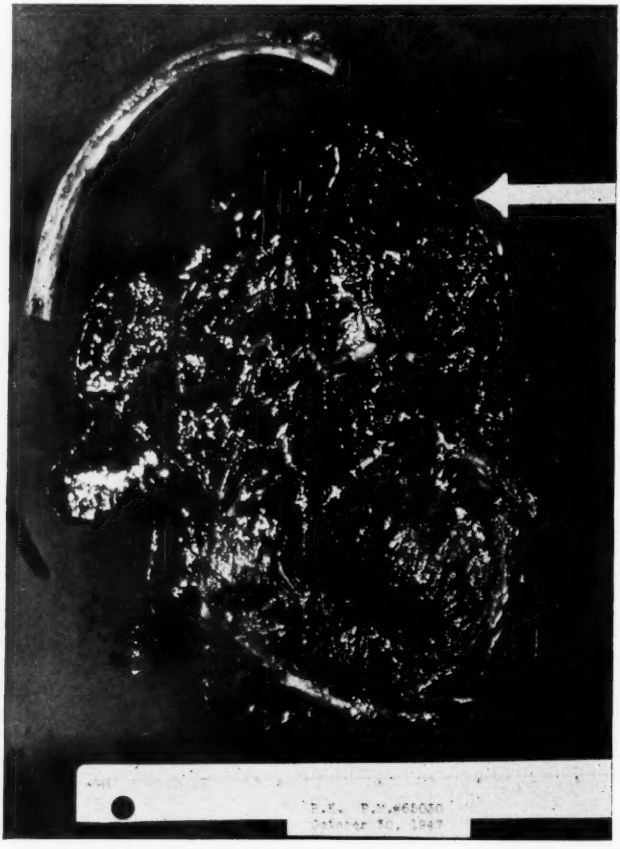

Fig. 8 (Case 2).—Photograph of pathologic specimen. The larger lower cyst is readily seen. The arrow points to one of the smaller cysts.

Physical examination revealed suppressed breath sounds in the left lower lobe and a shift of the heart to the right. Chest x-ray film showed gross distortion of the intrathoracic viscera due to a large ovoid lung cyst, measuring 6 by 7.5 cm. which crowded the entire base of the left lung and displaced the heart at least 3 cm. to the right. There was also another cavitation in the left apex which appeared triangular in shape. There was evidence of pneumonitis surrounding the cysts. The inflammatory component responded to treatment, but the tension cyst produced progressive mediastinal shift and severe restriction of activity. It was decided that decompression of the cyst was necessary before definitive surgery could be performed.

On April 22, 1946, a rib resection was performed (by A. J. V.) removing two inches of the eighth rib directly over the large lower cyst. The wound was packed and, four days later,

the cyst was opened, with excision of a section of the wall for pathologic study. A thoracotomy tube was inserted into the cyst and subsequently the mediastinum shifted to the left sufficiently to allow the child to be normally active (Figs. 5, 6).

The tissue was reported as "congenital bronchiolitic cyst."

The child left the hospital in good condition, with the tube in situ.

During the following eighteen months, he led a more or less normal life, and developed fairly normally, although he remained underweight.

On Oct. 28, 1947, the child was readmitted to the Carson Peck Memorial Hospital for definitive surgery. A total left pneumonectomy was performed by one of us (E. H. G.).

Fig. 9 (Case 2).—Photograph of patient, showing pneumonectomy scar and closed thoracotomy wound.

The fifth rib was resected subperiosteally and the pneumonectomy done by dividing the hilar structures first and the fistulous tract last. The cutaneous opening of the fistulous tract had been sealed off prior to the opening of the chest cavity. After excision of the tract, the main wound was closed with interrupted silk sutures in layers. Penicillin, 400,000 units, and 1 Gm. streptomycin were placed in the left chest cavity through a catheter which was removed as the last suture was tied. The cutaneous component of the previous thoracotomy wound was closed in layers after sealing off the main pneumonectomy wound. No drainage was used (Fig. 7).

The pathologic report was diffuse congenital cystic disease of the left lung with intervening atelectasis and pneumonitis (Fig. 8).

The child was discharged from the hospital on the seventeenth postoperative day in good condition (Fig. 9). It is now thirteen months (November, 1948) since the pneumonectomy. The child lives a normal life. He is extremely active. He is now 4½ years old and is growing at a normal rate.

COMMENTS

Complications of congenital cysts are of three kinds. The first is infection of the cyst wall or suppuration within the lumen. This may be of serious nature. The patient in Case 1, although only 11 weeks of age at the time of operation, had had two critical episodes of suppurative disease.

The second complication is altered physiology as seen in Case 2. Cysts may be connected to the respiratory tract by relatively small or angulated passages, so that air enters, but becomes entrapped. Thus, a positive pressure can be built up within the cyst, so that the structure becomes greatly distended and compresses adjacent lung tissue and mediastinal organs to the opposite side of the chest. Because of this, respiratory distress can be so extreme that the situation may be incompatible with life unless some form of relief is promptly instituted. This complication led to preliminary decompression in the second case.

The third type of complication is rupture of the cyst into the pleural cavity with possible tension pneumothorax and empyema.[8]

DISCUSSION

Numerous excellent reviews of cystic disease of the lung have appeared in the now voluminous literature of the subject.[10, 11, 21, 27, 28, 33, 35] We shall limit our discussion to congenital cysts. Acquired, dermoid, echinococcal, cysts of indeterminate origin, and rarer ones such as aberrent gastric cysts are not within the scope of the present paper.

Congenital cysts are less common than acquired cysts which appear as a consequence of inflammatory reactions. Congenital pulmonary cysts may be single or multiple, localized or scattered; they may or may not communicate with a bronchus and may contain fluid, gas, or both.[15, 30] Such an abnormality of the lung may arise as a solitary structure from an accessory bronchial bud. The cyst may appear as a pedunculated affair, situated between pulmonary lobes or else projecting in front of or behind the lung root. Such a solitary lung cyst was found between the upper and middle right lobes in Case 1. This was in addition to a diffusely cystic upper lobe. More frequently, however, cysts develop within the parenchyma and under such circumstances they are quite likely to be multiple. This was true of the second case. Congenital lung cysts are occasionally bilateral, but, fortunately, they are more often limited to one lung.

Whereas acquired cysts presumably do not appear until early childhood at the earliest, it is conceivable that tissue predisposition, i.e., weakness of the elastic or muscular layer of the bronchus,[40] may lead to cystic malformation at a very early period. Thus, some forms of cystic disease—localized cystic bronchiectasis, for example—might be considered congenital if they appear in early infancy and acquired if the tissues withstand the strains for a longer

period of time. Certain pathologic considerations[3] fortify this concept. Most pathologists consider any cyst lined with a bronchial epithelium, the individual cells of which are mucus-secreting, ciliated and columnar in type, as congenital in nature.

Congenital cysts are usually bronchial in origin[3, 5, 12, 26, 30] but rarely may be enterogenous[14] or lymphangiomatous.[30] Anspach and Wolman[30] reviewed the theories of pathogenesis prevailing in 1933 and suggested that most congenital cysts are fluid-containing at birth and frequently rupture or spill over into a bronchus after birth, becoming air-filled cavities. The clinical course and x-ray findings of Case 1 would suggest this turn of events.

The symptomatology of a given cyst depends on the original anatomical status together with postnatal changes affected by respiratory action and infection. A small cyst may give no signs or symptoms and occasionally larger cysts may persist into adult life before their presence is suspected.[6, 28] The pattern described by Anspach and Wolman has been followed, generally, in the subsequently reported cases and was true of our two cases.

The physical signs, depending on the stage and type of pathology, are, of course, extremely variable. Schenck[34] has tabulated the signs and symptoms and their relative frequency. These included almost everything that can be imagined as occurring with disease of the lung.

The x-ray features of congenital cystic disease of the lung have been described by many competent observers.[22, 28, 30, 33] The problems of differential diagnosis are often considerable. Fluid-containing cysts, before rupture into a bronchus, and depending upon the element of infection, may suggest inflammatory consolidation, atelectasis, empyema, or even solid tumors. Atelectasis, as in the first case, is apparently the most frequently simulated picture. Air cysts, in which a fluid level may or may not be present, necessitate differentiation from obstructive emphysema,[17] bullous emphysema, loculated pneumothorax, hypropneumothorax, pulmonary abscess, acquired bronchiectasis, and tuberculous cavitation. In the neonatal period, the possibilities are limited and the roentgenologist, given a complete clinical history, can often make the diagnosis.

Boyd,[40] in his sixth edition of *Surgical Pathology* (1947), states, "It is not possible to write a satisfactory account of cysts (congenital) of the lung for the pathology is so confused." A review of the literature would seem to indicate that the difficulty arises out of the fact that the original anatomy, which includes variable degrees and patterns of congenital deformity, may be altered by mechanical factors or infection either alone or in combination. Through all of the controversy, there is but one pathologic feature more or less universally accepted, that the type of lung cyst which develops from a bronchial bud is of necessity, at least in its primordial state, lined with mucus-secreting, ciliated columnar epithelium, characteristic of bronchial mucosa. Most recent authors insist upon this as the basic histologic feature of an undisputed congenital cyst.[3, 4, 5, 9] Variations and all gradations from the typical to a flattened cuboidal type of epithelium have been described.[6, 10, 19, 40] It is understandable that infection might destroy the original epithelium and replace it with granula-

tion tissue and eventually with a less characteristic cell type. The walls and supporting stroma of the cysts have also been variously described and, unfortunately, the few reports of pulmonary cysts in stillbirths[39] do not solve the problem because of developmental factors and the variety of findings which might be postulated. Dickson and associates[3] (1946), in reviewing the histologic features of twenty-two pulmonary cysts, suggest that disorderly arrangement and erratic grouping of the supporting stromal structures (cartilage, smooth muscle, elastic tissue, and glands) are characteristic of most congenital cysts. They constrast the extreme variability of the supporting tissues and the frequent dominance of one or the other of the stromal elements in the congenital cyst with the orderly arrangement of these structures in simple bronchial dilatation. It is of significance, however, that their youngest patient was 7 years of age and that all but three of the twenty-two cases showed signs of infection. They readily concede that absolute classification is difficult and, at times, impossible because of the interplay of congenital and acquired factors.

Various forms of surgical therapy have been employed. A needle can be passed through the chest wall into the cyst cavity permitting withdrawal of entrapped air. Improvement is likely to be immediate and dramatic but it is temporary, as the air will again accumulate. Furthermore, a connection to the pleural space may be made and a tension pneumothorax result. Aspiration, with a fine needle, should be employed only as a temporizing measure, while preparing for more adequate therapy.

A trocar may be employed through which a catheter is threaded for the establishment of more prolonged aspiration. In this form of therapy, it is preferable to use a small mushroom catheter so that its bulbous end can be pulled against the inside of the cyst wall preventing escape of air into the pleural space.[4] Constant application of suction should keep the cyst completely collapsed. This is of value in preparing for more extensive surgery. One of us (A. J. V.) elected a modification of this method to bring the second of our cases to definitive excisional surgery in the best possible condition. The use of sclerosing fluids is precluded by the possibility of communication of the cyst with a bronchus.

Marsupialization of the cyst onto the chest wall with destruction of its membrane by curettage, cauterization, or packing has points in its favor. The external opening, however, produces considerable danger. Infection may gain entrance to the regional lung, a problem which would be difficult to control. The greatest objection to the method is that congenital cysts are prone to be multiple. Hence, marsupialization should be practiced only when the surgeon is certain he is dealing with a solitary cyst.

Enucleation of the cyst or the removal of pulmonary tissue is by far the treatment of choice. Segmental resection, lobectomy, or even total pneumonectomy may be necessary. In Case 1, right upper lobectomy and enucleation of an extrapulmonary cyst were sufficient. In Case 2, a left total pneumonectomy was necessary to remove all the pathology. The presence of a bronchocutaneous fistula in this case presented an added technical difficulty.

Anomalous blood vessels are frequently associated with congenital cystic disease. They may be of considerable caliber and are notoriously variable in origin, even transversing the diaphragm to take an anomalous position in the thorax. It is of prime importance that the thoracic surgeon dealing with the excision of cystic disease of the lung should be cognizant of these facts. Adhesions in a location usually divided with impunity may conceal large vessels; if these are not ligated, the operation would prove disastrous.

SUMMARY AND CONCLUSIONS

Two cases of successful excisional surgery for congenital pulmonary cystic disease are presented. The first case is a lobectomy in an 11-week-old baby. The second case is a left total pneumonetcomy in a 4-year-old boy.

The literature is reviewed. The diagnosis, symptomatology, pathogenesis, pathology, complications, and treatment are discussed.

Excisional surgery, we believe, is the treatment of choice in congenital cystic disease of the lung. Infants and young children withstand thoracic surgery well.

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SURGICAL WOUNDS OF THE LUNG

The Mode of Healing of Pulmonary Tissue

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STRUCTURAL changes in the lung have been clearly described in infectious and neoplastic diseases of the lungs. Such is not the case, however, in pulmonary trauma due to accidents or surgical interference. A diligent search in the medical literature revealed very little work done on the subject. In 1929, Olch and Ballon[1] described the development of scar tissue on the lung resulting from experimental wounds. No other paper appeared until 1944 when Montgomery[2] described the mode of healing of experimental wounds of the lung. More recently, Porter, Higgins, and Claggett[3] reported, in abstract, experiments carried out on this field. The complete article, as far as we know, has not, as yet, appeared in any publication.

A number of related articles dealing with the pathologic physiology of the lung are worth mentioning. The monograph of Cecil K. Drinker[4] on pulmonary edema describes beautifully the role of capillary anoxia in the diffusion of exudates from the alveolar capillaries into the alveoli. Macklin's[5] description of tracheobronchial musculature and the physiologic mechanisms involved in normal respiration, as well as in pathologic states, is worthy of mention. The basic facts concerned in wound healing described by Arey,[6] though not directly concerned with changes in the lung, may well be applied to healing of pulmonary tissue. The role of phagocytosis in the handling of foreign material in the lung has been aptly discussed by Robertson.[7]

In thoracic surgery a great deal of progress was made since the report of Graham[8] on a successful pneumonectomy for carcinoma of the lung. A great step forward was made by Blades and Kent[9] with the individual ligation technique for pneumonectomy. The covering of the bronchial stump with pleura has prevented a large number of annoying and even fatal bronchial fistulas in the patients requiring a total pneumonectomy. Patients who may require only a subtotal pneumonectomy generally do very well if some pulmonary tissue is left to be used as a covering pad of the bronchial stump.[10] Not all pathologic states in the lung require complete resection of the lung and techniques have been described even for segmental resection of the lung.[11] We have felt for many years that surgery of the lung, unless definitely indicated, need not be too drastic or mutilating.

In benign lesions every effort ought to be made to preserve as much normal lung as possible for future necessities. The less normal lung necessarily is sacrificed, the more lung is left to serve for the general economy of the patient for future emergencies.

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With this principle in mind we carried out a series of experiments over a period of years in the hope of determining what happens to the remaining portion of the lung which has been operated upon, after surgical trauma and suture. We studied the effects of such injuries as crushing and puncture wounds, tears, incisions, resection of wedges of lung, and finally resection of lung tissue at right angles to the axis of the bronchovascular elements. We also studied the response of the lung to absorbable and nonabsorbable suture material. The effects of these procedures were studied by sacrificing the animal immediately after the experiment, at 90 minutes, at 24 to 30 hours, at 48 hours, at 5 to 7 days, at 10 to 14 days, at 1 month, at 6 months, and at periods of four years or longer.

The peculiar structure of the lung is instrumental in the development of certain basic changes resulting from injury or infection. Anatomically the lung is so constructed as to expose as much of the capillary blood supply as possible to the alveolar vapors. Because of this fact, the human lung is made up of approximately 750 million alveoli which are connected with the atmospheric vapors through the tracheobronchial tree. The vascular and lymphatic supply of the lung follows much the same pattern of distribution as the tracheobronchial tree.[4] The capillary distribution of the alveoli is so constructed that an enormous amount of blood is present in the lung at any one given time. By means of surface stereomicroscopic studies on the alveoli of living dogs, frogs, and alligators, we learned[12] that the alveolar wall is practically flooded with blood in the one-cell capillaries which drain the blood into larger venous capillaries at the interalveolar junction. This is also true in the intra-alveolar septa that project into each alveolus. These capillaries connect with the larger ones at the interalveolar junction. The flow of blood is in one direction and gives the impression of waves seen in wheat fields when the wind blows over them.

The lung having one root at the primary bronchus may be considered fan shaped if we can imagine a fan projecting in all directions and planes. Because of this structural pattern, any distortion of the normal contour of the lung has a tendency to bring the bronchi and vessels in closer apposition and thus these elements assume a contour of a number of strands bunched together. In our description of this pattern we shall refer to this change as *strand formation.*

The lung has all the opportunities for proper drainage through the tracheobronchial tree. With the exception of the interstitial tissue, it is exposed to the atmosphere. In the absence of bronchial occlusion most foreign particles, including pus, may be expelled by cough or postural drainage. Furthermore, the tracheal mucosa is covered with ciliated mucous epithelium. This pattern extends down to the respiratory bronchioles.[5] The cilia have a very active upward movement and may aid in directing toward the trachea any particulate matter or mucus that finds its way into the respiratory passages. The goblet cells of the mucous layers of the epithelium assist in this process by lubricating the foreign particles with mucus. The extensive musculature of the bronchi, by narrowing and dilating the lumen and by elongating and shortening the bronchial trunk, do their share in eliminating noxious matter that may find its way into the respiratory passages. The act of coughing plays a very important role in the expulsion of noxious matter from the tracheobronchial tree.

The treelike branching of the bronchi and the blood vessels is terminal. There is no collateral branching. It is for this reason that occlusions of bronchi generally result in atelectasis. By the same token occlusions of the vessels result in local blocking of the blood supply to cause infarction.[15] The presence of alveolar pores has been described and was given as a means of collateral respiration. Such pores, however, are not sufficient to take care of large groups of alveoli, especially those arising from a bronchus independent of the one supplying air to a given area.

In our work we have found that the lung produces a thick, gummy, yellowish secretion which serves to plug up lacerated or injured alveoli and small bronchi. This secretion will plug up the lung tissue so that in a short time air leakage may stop. This process is enhanced by the contraction of the lung which follows when air finds its way into the pleural cavity.

Healing of lung tissue is so prompt that many minor injuries occurring in the lung heal without even producing clinical symptoms. For example, when a small perforation occurs in the lung from a rupture of a pleural bleb or a puncture of the lung surface with a needle (as in the case of artificial pneumothorax) air escapes into the pleural cavity. This air is sucked out into the pleural space by virtue of the existing negative intrapleural pressure. The lung then begins to collapse and by doing so the alveoli are compressed, the bronchovascular elements contract and become more closely approximated. As the pulmonary tissue juices seal off the puncture wound, no more air or fluid exudes from the injured surface of the lung. Within five to seven days the repair processes have been completed. Coincidentally, the air in the pleural cavity is absorbed, the lung re-expands and functions as before. It is interesting to note that after seven days no evidence of injury may appear in the lung, except some local thickening of the visceral pleura.

If the lung is exposed by thoracotomy when such an injury occurs this process of healing may be facilitated by gently pressing the injured portion of the lung with the thumb and index finger or by a gentle stroking massage, with slight pressure over the denuded area, at the point of leakage. In this way, the alveoli become contracted and the pulmonary tissue juices seal off the alveoli, so that air leakage is eliminated. Such a seal becomes sufficiently secure to prevent further leakage even when the lung is distended to its normal volume immediately after the sealing process takes place. When the visceral pleura is completely sealed the negative intrapleural pressure gradually allows air to be sucked into the contracted alveoli and a normal distention occurs.

If air is introduced into the lung under increased pressure, up to 60 mm. Hg, or more, then one or all of the following complications may develop[13]: 1. The intra-alveolar pressure may rise so high as to force air into the capillaries and result in air embolism. 2. The normal cohesive power of the visceral pleura may be overcome and a pleural bleb may result on the surface of the lung. If the tension is high enough to rupture the bulla, the air will leak into the pleural cavity and result in a pneumothorax. 3. If the intrabronchial pressure is unusually high (up to a maximum of 100 mm. Hg even for an instant) the hilar pleura may become detached and cause mediastinal, retroperitoneal, and interstitial emphysema. It is obvious, of course, that when a larger bronchus is

injured only a suture of the bronchus can seal such a leak. When a fairly large bronchus is involved, the air continues to escape into the pleura and if the mediastinum is fixed and there is no ball-valve opening, the intrapleural pressure rises to a point equal to that of the intrabronchial pressure and thus the air leakage stops. If a small bronchus is involved, then the contraction of the lung along with the plastic pulmonary tissue juices results in an occlusion of the leaky bronchus. It is for this reason that the patient with a spontaneous pneumothorax may safely be left alone unless he has evidence of respiratory embarrassment. Thus, most cases of spontaneous pneumothorax clear up without aspiration of the air from the pleura provided the cough is controlled and thus increased intrabronchial pressure is eliminated.

EXPERIMENTS AND RESULTS

When the lung tissue is compressed gently with rubber-tipped clamps no appreciable changes occur. In this way, the lung may be sutured aseptically without the introduction of infected materials that may leak from the bronchi. However, if the lung is forcibly crushed by an artery forceps, a dent appears at the point of crushing. The proximal and the peripheral portions of the lung, on either side of the crush injury, contract and expand normally. If the intrabronchial pressure is increased, the dent will gradually disappear and the lung will assume grossly its original contour. All that remains on the surface is a pink line at the point of crushing. Increased intrabronchial pressure stretches the alveoli to their normal capacity.[14] This principle can be profitably utilized for the care of congestive changes of the lung causing consolidation as found in pneumonias. When the crushed alveoli are stretched to their normal volume, the microscopic appearance of the area reveals no deviation from the normal. If the alveoli are not distended, one can see a pool of red blood cells at the area of crushing with a definite line of demarcation between the crushed area and the normal structure (Fig. 1). The alveoli are completely filled with fluid and red blood cells. There is no evidence of inflammation immediately after crushing. After forty-eight hours one sees a diminution in the number of red cells and an increase in the amount of plasma. The changes are limited strictly to the area of crushing. By the fifth day the alveoli begin to show air intermingled with pools of red blood cells. By the tenth day the area appears completely normal except for some thickening of the interstitial elements.

When the lung is incised along the axis of the bronchovascular tree one may cut smaller vessels and bronchi which may run crosswise or obliquely at the incised area. In such a case the larger cut vessels and bronchi may be closed at the cut ends by ligature or suture and heal promptly. If, however, the bronchus or the nutrient vessel is ligated proximally en masse an atelectasis or infarction results in the peripheral portion of the lung. Such changes[15] may heal spontaneously or may result in an abscess and possible rupture of the lung (Fig. 2). When the lung is cut at right angles to the bronchovascular tree, the healing occurs without any possibility of infarction. It goes without saying that the proximal portion of the lung should be gently compressed with rubber-tipped forceps to avoid leakage of infected contents of the tracheobronchial tree into the sterile pleural cavity. The proximal stump may be sutured with a single or a double row of sutures of fine silk, plain, or chromic No. 00 or 0 catgut. Such a suture makes the stump airtight and watertight and when the lung is distended only the portion of the lung in the immediate vicinity of the suture does not contain air. If a wedge is amputated it is essential that the base be at the periphery of the lung and the apex be pyramided toward the base. In this way, the cut vessels and bronchi are only the ones supplying the wedge and have no peripheral connection with adjacent remaining lung.

When the animal is sacrificed immediately after the experiment one finds the alveoli at the site of the suture filled with red blood cells. There is a gradual diminution of the

hemorrhagic changes immediately beyond the suture line and within 1 to 2 cm. the lung appears normal. Soon afterwards the blood elements and the capillary endothelium set up the processes of healing of the traumatized portion of the lung by organization of fibrin and subsequent steps of tissue repair.[6] Thickening of the interstitial elements occurs to a greater or less extent. The alveoli that have been filled with blood and plasma attempt to drain out their contents and begin to fill up with air. In ten days to two weeks, the traumatized areas show newly formed bronchial elements, some thickening of the interstitial tissue, and in four weeks there is a return to normal. In areas where the tissues are held by an unabsorbable suture the picture differs somewhat. Here the bronchovascular elements show strand formation between the sutures. The alveoli in such areas are smaller in size and their walls appear thickened (Fig. 3).

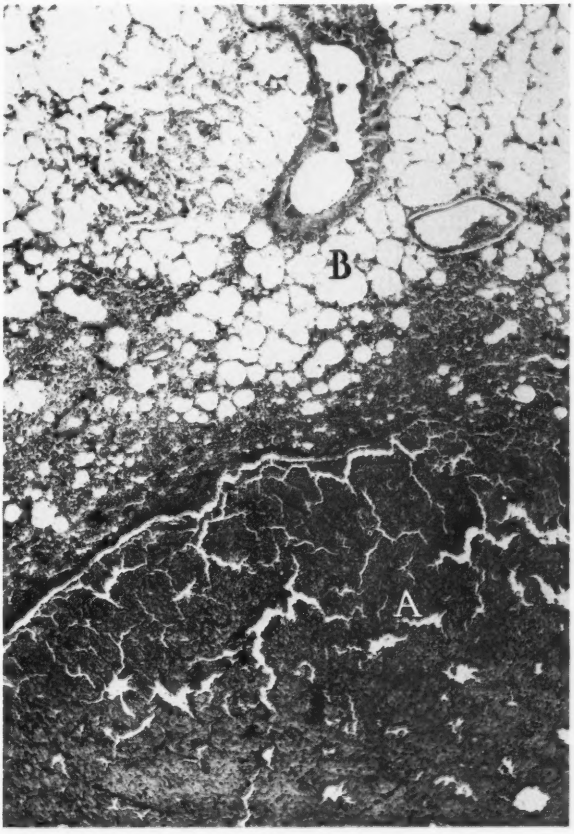

Fig. 1.—Microscopic section showing area of hemorrhage with a line of demarcation between normal (see *B*) and crushed lung (see *A*). (×45.)

In the analysis of the pulmonary response to trauma, the description of the microscopic findings under various procedures and at different time intervals may give a more clear-cut view.

In Experiment 95 the lung was crushed with a long artery forceps and immediately afterwards the lobe was resected. The crushed portion was not distended by increased

intrabronchial pressure before the lobectomy. There was a dent at the site of the crush and both the proximal and distal portions appeared normal. The dented area was red and atelectatic. Microscopically, at the site of the crushing the alveoli contained no air but were filled with pools of red blood cells. On either side there was a gradual appearance of air-containing alveoli. Within a few millimeters beyond this area the lung appeared normal (Fig. 1).

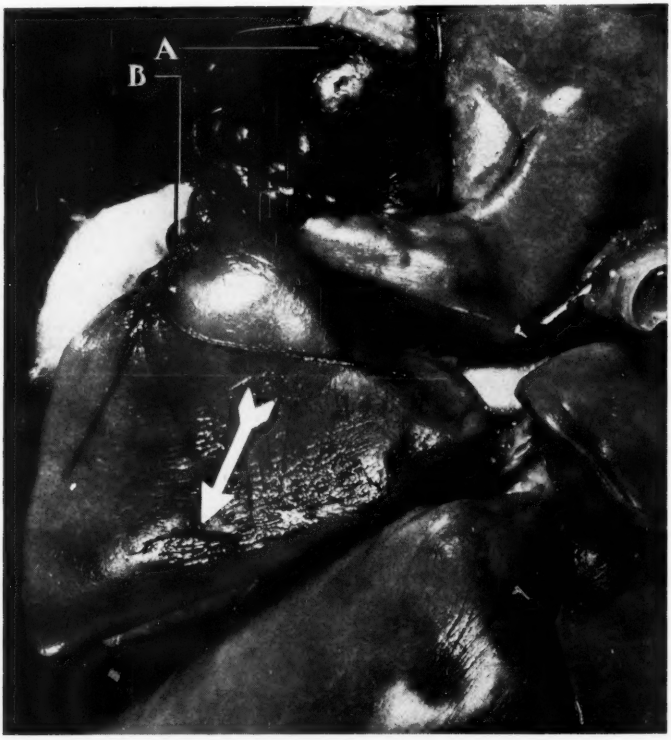

Fig. 2.—Gross specimen 27 hours after ligation of nutrient artery. Note area of infarct in tip of upper lobe (see *A*). Arrow shows effect of an incised wound on surface of lower lobe. Gentle pressure stopped leakage of air and blood. No suture applied. The area was completely airtight and watertight before closure of the chest cavity. Tip of lower lobe shows the effect of suture (see *B*).

In Experiment 97 the dog was sacrificed within ninety minutes. A left thoracotomy was performed under Nembutal narcosis and positive pressure artificial respiration. The tip of the left lower lobe was cut at right angles to the axis of the bronchovascular tree. This was done after gentle pressure was applied with a rubber-tipped intestinal clamp to control leakage of blood and air at a point well enough proximal to the site of amputation. A double row of continuous locking sutures with No. 0 size 10-day chromic catgut made the stump airtight and watertight. A wedge was also cut with the apex reaching close to the root of the lung and the base reaching the peripheral tip of the lung. The stumps on either side were sutured individually with a double row of fine silk sutures. The stumps were not approximated to one another. The chest was closed in layers and the air from the pleural cavity was aspirated just before the final skin sutures were applied. The dog showed no reaction or shock from the experiment. One and one-half hours after the

experiment was finished the dog was sacrificed by injecting intravenously a lethal dose of Nembutal to cause a respiratory-center paralysis. Death occurred without any struggle on the part of the animal. In this way, no changes in the lung resulting from struggle had to be dealt with. We have found that even a mild struggle in the dog causes rupture of capillaries with resultant hemorrhages.[12] At autopsy the right lung appeared normal. The left lung at the site of the suture line showed the stumps to be liverlike in consistency and color (Fig. 2). The remaining lung appeared normal.

Fig. 3.—Appearance of the lung 90 minutes after suture. Note "strand formation" around the suture. The alveoli in the immediate vicinity are filled with blood elements. (×45.)

Microscopically, the sections from the stump of the lower lobe showed infiltration of the interstitial elements with areas of microscopic hemorrhages. The bronchovascular elements showed no appreciable change. There was atelectasis at the site of the suture but there were normal alveoli just beyond the sutures. In general, with the exception of islands of microscopic hemorrhages at the vicinity of the sutures and strand formation between the sutures, the lung appeared normal.

The sections of the stump of the upper lobe showed changes similar to those in the lower lobe. The bronchovascular elements around the suture showed strand formation in the direction of the pull of the two ends of the suture (Fig. 3).

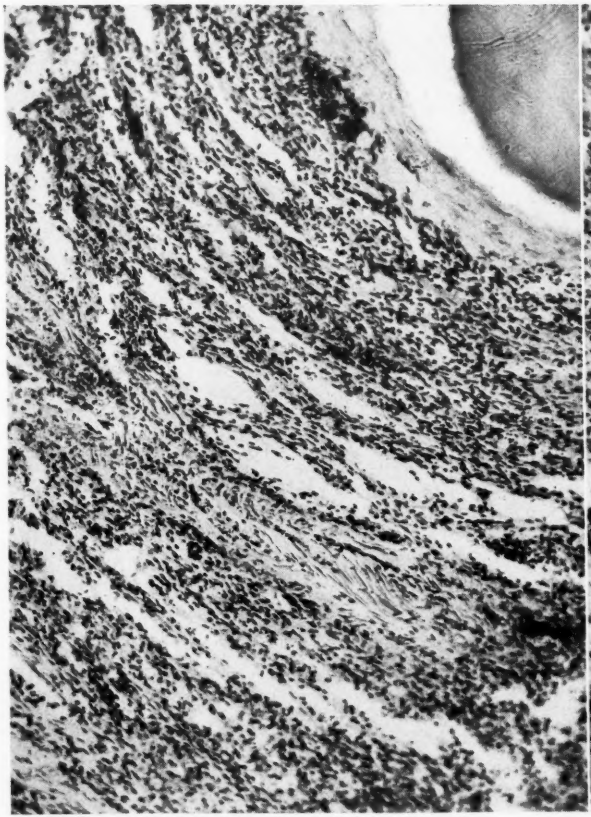

Fig. 4.

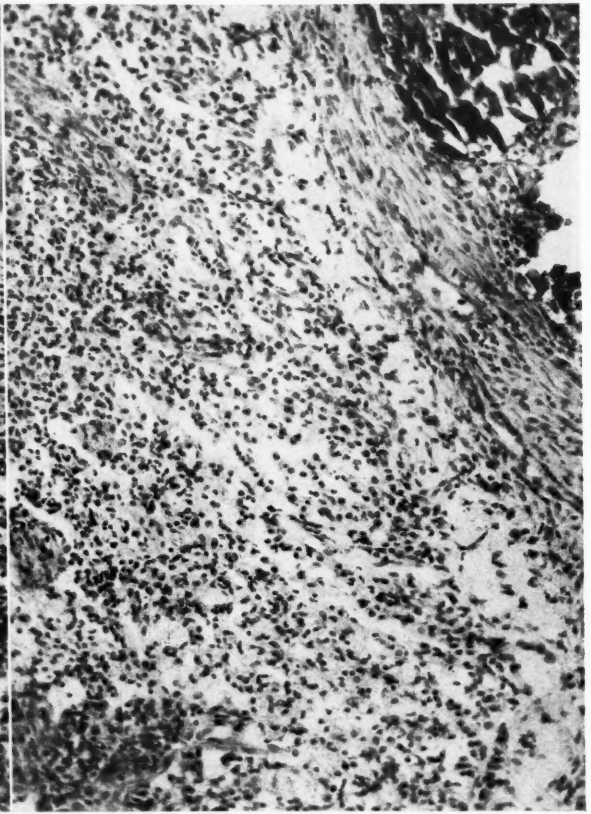

Fig. 5.

Fig. 4.—Appearance of the lung 48 hours after suture. At upper right-hand corner the suture is seen. Fibroblasts and collagen fibres may be clearly seen just beyond the suture. Normal alveolation is replaced by "strand formation." (×120.)

Fig. 5.—Appearance of lung 7 days after suture. At upper right-hand corner the catgut shows evidence of absorption. Immediately beyond the suture there is thick granulation tissue showing "strand formation." Just beyond this area fibroblasts and macrophages are seen in large numbers. Aleveolation is quite evident. (×120.)

and macrophages are seen in large numbers. Alveolation is quite evident. (×120.)

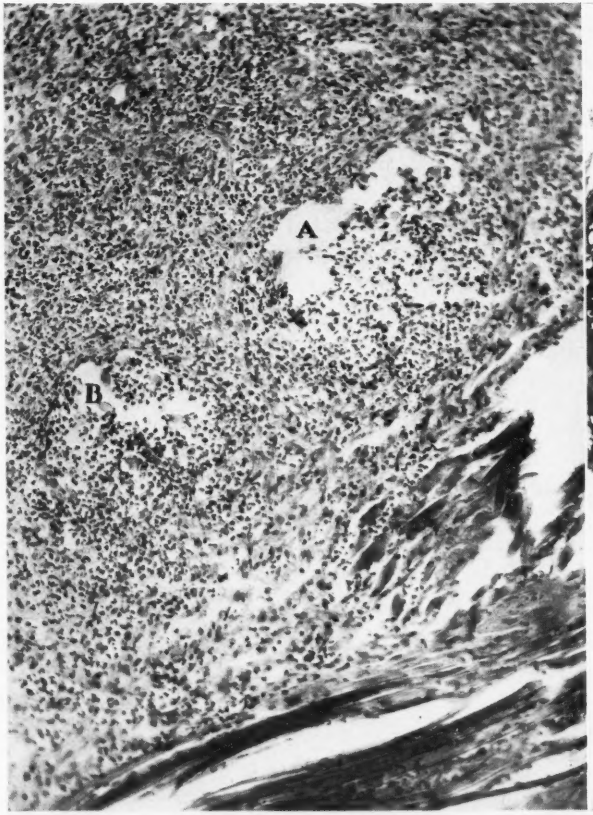

Fig. 6.

Fig. 7.

Fig. 6.—Appearance of the lung 14 days after suture. Note the fibers of catgut with phagocytes imbedded. At *A* and *B* the catgut is almost completely absorbed with the exception of a few particles of catgut containing phagocytes. Just beyond the suture the granulation tissue shows fibrous tissue development. (×120.)

Fig. 7.—Low-power appearance of a subtotal pneumonectomy stump four years after operation. Note the dimpling of the bronchial lumen and the distortion of the bronchi. Also note the dense fibrous tissue present between the bronchi. (×20.)

Experiment 98 was done to study the pulmonary stump at twenty-seven hours after the experiment. The tip of the left lower lobe was resected at right angles to the axis of the bronchovascular tree. A slit was made in the left upper lobe to a point where a larger vessel was cut. The vessel was ligated with a mass ligature well above the cut area. The cut edges were sutured with No. 00 chromic catgut. The upper portion of the lower lobe was incised with the scalpel on the outer surface and the incision was extended to a length of 3 cm. along the axis of the bronchovascular elements. Air bubbles and frothy contents appeared at the cut surface. After stroking the cut area with gentle pressure the air bubbles ceased to come through and the area was not distended further. At autopsy the right lung was normal. There was some injection of the dog's thin mediastinum. The left lung was adherent to the chest wall at the site of the thoracotomy by means of thin fibrinous adhesions. These peeled off easily. The tip of the upper lobe, where a mass ligature was placed, was purple in color, and liverlike. The tip of the lower lobe was normal except at the site of the suture line where it was atelectatic, dark red, but airtight and watertight. The site of the puncture showed no leakage of air or fluid and the cut edges were slightly separated from each other (Fig. 2). Microscopically, the area of surface tear showed a hemorrhage at the gap between the torn edges. Fibrin was present in the hemorrhagic area. The cut edges showed the alveoli and bronchioles filled with blood extending proximally for a few millimeters. From there on there was a gradual return to normal. The tip of the lower lobe showed strand formation in the direction of the pull from the sutures. The alveoli were compressed and filled with blood cells. The interstitial elements appeared to separate more and more from each other and assume a more normal pattern. The area of infarction showed complete filling of the alveoli with blood. The normal pulmonary pattern was gone. At the edge of the infarct there was a definite line of demarcation between the normal structure and consolidated area.

Another animal with a similar operation was sacrificed forty-eight hours after the experiment. The pleuropulmonary adhesions were still fibrinous in type. About 10 to 15 c.c. of thin bloody fluid in the chest were present. All sutures held well. The sutured area at the tip of the lung was lighter in color than at twenty-seven hours. The infarction in the upper lobe appeared similar to the findings at twenty-seven hours. Microscopically, the opposite lung showed areas of moderate emphysema. In an area between two sutures the interstitial elements were closely packed together producing strand formation in the direction of the pull from the suture. The alveoli were occluded and filled with some red blood cells and a few polymorphonuclear leucocytes. Fibroblasts were present in large numbers (Fig. 4).

After five to seven days the pleuropulmonary adhesions which are invariably present at the site of the thoracotomy became fibrous but still stripped easily. The pleura over the site of operation showed some thickening. The lung at the sutured area where the excision was done at right angles to the axis of the bronchovascular tree appeared normal. The consolidation was nearly gone. The bronchi showed some flattening or distortion but the lumen was intact and not completely occluded. In some areas the mucosa had papillary projections into the lumen. Newly formed bronchi were seen forming new air ducts between the new alveoli and the stem bronchus. In the immediate vicinity of the suture there was no tear in the lung. Just adjacent to the suture the strand formation persisted. Alveolation became more evident. The interstitial tissue was thickened. A large number of fibroblasts and macrophages were present. The alveoli were filled with serum and gradually integrated to the normal lung structure (Fig. 5).

By the fourteenth day most of the absorbable suture material dissolved, and the space held by the suture was filled with fibroblasts (Fig. 6). The smaller bronchi began to assume their normal contour. The alveoli showed aereation. There was an interalveolar wall thickening. In areas where the nutrient vessel had been blocked one might see evidence of fibrosis, or evidence of central breakdown with abscess formation.

Within four weeks' time the lung appeared normal except in areas containing unabsorbable sutures. The sutures remained intact. The strand pattern persisted around the suture and the interstitial tissue was thickened. The alveoli were small in the imme-

diate proximity of the suture and gradually appeared larger till a normal pattern was reached at some distance from the suture. The portion of the lung operated upon is invariably adherent to the chest wall, the diaphragm, or the pericardium by dense fibrous adhesions.

At intervals longer than four weeks the lung appeared practically the same. We obtained sections from one dog that was sacrificed four years after a subtotal pneumonectomy. The stump was 2 by 2 cm. It was covered by a tough fibrous pleural covering. The stump was airtight but air containing. It was adherent to the chest wall. A low-power microscopic view showed dimpling of the larger bronchus and distortion of the contour of the smaller bronchi. There was a large amount of fibrous tissue around the bronchus. There were some areas of normal alveolation and also areas of emphysema (Fig. 7).

These experiments prove beyond doubt that pulmonary tissue heals promptly. They also prove that lung sutures hold fast and do not tear the lung. Because of the extensive number of capillaries, the endothelial cells which play an important role in healing, the lung is better adapted to reparatory processes than many other structures in the body. The presence of smooth muscle[5] extending down to the minute ramifications of the bronchial tree and even the alveoli themselves helps to give sufficient body to the lung so that a suture may hold well and not cause a tear. On the surface of the lung the endothelium of the visceral pleura promptly comes into play to bridge any gap and produce a satisfactory apposition and a good scar. The collagenous tissue juice of the lung has a definite plastic effect. This no doubt assists in the reparatory processes present in the blood plasma and the blood cells.[6, 7]

It is obviously important not to introduce any infectious material into the wound during the suture of the lung. A mild enough pressure to overcome leakage of air and blood at the proximal portion of the lung with rubber-tipped forceps will prevent leakage of contaminated bronchial contents. Care must be taken not to crush the lung and thus no injury may follow. If this occurs accidentally, one may introduce compressed air at a pressure sufficient to distend the crushed elements of the lung. Healing then is prompt and no gross changes will occur.

Because of the terminal branching of the bronchovascular elements of the lung, it is very important that any excision of lung tissue must be done at right angles to the bronchovascular tree. This routine avoids injury to bronchovascular elements supplying neighboring peripheral lung segments. Thus infarction and pulmonary atelectasis do not result. If a wedge is resected it must be cut in such a way that nutrient bronchi or vessels supplying neighboring pulmonary segments are not injured. Thus atelectasis and infarction are prevented.

The lung tolerates unabsorbable sutures and little or no reaction follows. Aside from "strand formation" and diminution in the size and capacity of immediate alveoli no other reaction is noticeable. Absorbable sutures dissolve within a reasonable time and, with the aid of the macrophages, phagocytosis and solution of the suture occur.

SUMMARY

1. In the absence of infection lung tissue heals promptly and by primary intention after surgical trauma.

2. The interstitial elements of the lung are stranded together in the direction of the pull of the suture.

3. Occlusion of a stem bronchus invariably results in atelectasis of the peripheral segment of the lung.

4. Occlusion of a nutrient vessel invariably results in an infarct of the peripheral pulmonary segment.

5. Sutures of the lung do not cause tears in the organ.

6. Unabsorbable sutures remain intact and cause only a strand pattern.

7. Absorbable sutures are dissolved and absorbed leaving little or no trace of their presence.

8. A plastic tissue juice produced by the lung assists in sealing lung injuries. This juice restores the airtight and watertight function of the visceral pleura.

9. Resections of segments of the lung need not reach the root and may be made just beyond the area of pathology. The proximal segment heals promptly provided the stem bronchus and nutrient vessel are not ligated at a point that occludes air and blood supply to adjacent segments.

10. Resections of the lung at right angles to the axis of the bronchovascular elements prevent occlusion of nutrient bronchi and vessels leading to adjacent segments of the lung.

11. If a wedge is to be removed it should be pyramided. The apex of the triangle should be at the area of the root of the lung and the base at the periphery. Thus nutrient bronchi and vessels are least likely to be injured.

12. These experiments prove that it is not necessary to make root resections of lobes, lobules, or segments. Thus as much healthy lung as possible may be preserved for the future economies of the patient.

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CHRONIC PNEUMONITIS: ITS CLINICAL AND PATHOLOGIC IMPORTANCE

Report of Ten Cases Showing Interstitial Pneumonitis and Unusual Cholesterol Deposits

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CLINICAL ASPECTS

FOR many years a clinical entity variously described as subacute, chronic interstitial, or fibrous pneumonia has been recognized.[1-9] An outstanding characteristic of the condition is its subacute or chronic clinical course. The onset may be insidious, but in the majority of cases the disease has been considered a sequela to bronchopneumonia, lobar pneumonia, persistent collapse following bronchial obstruction, or fluid accumulations. However, a definite statement concerning its origin has often not been possible. In any event, the end result is essentially the same, namely a chronic pneumonitis.

Only in recent years has surgical extirpation of inflammatory lesions of the lung provided specimens of early stages of chronic nontuberculous inflammatory disease. In the past patients afflicted with this disease either recovered or succumbed as a result of progression of the condition. The autopsy findings in such cases tend to be those of advanced stages of the lesion. During the past few years a small group of cases which conform to a fairly distinct clinical pattern and which pathologically have shown a characteristic chronic interstitial inflammatory process has been observed. The lesion in these cases was characterized by marked fibrosis and unusual deposits of cholesterol and cholesterol esters contained in large mononuclear cells. Although a similar histologic picture is sometimes seen distal to bronchial obstruction, or around chronic abscesses and severely infected bronchiectasis, these conditions have not been present in the group of cases reported here. The etiology has not yet been determined. The descriptive term "chronic pneumonitis, cholesterol type" is used to designate the condition.

The cases of ten patients with this condition who have been treated by surgical resection make up the subject of this report. In nine a lobectomy was performed. In one a pneumonectomy was required. The case histories and pathologic anatomy are presented in some detail. Some of the clinical data are summarized in Table I. Nine of the ten patients were males. The only female was a 12-year-old girl. The ages ranged up to 67 years. The disease was initiated by an acute respiratory infection in one-half the patients, and in the remainder the onset was insidious. None of these patients was under observation at the Massachusetts General Hospital during the initial stages of the disease,

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TABLE I

CASE	UNIT NUMBER	AGE (YR.)	SEX	OCCUPATION	INITIAL SYMPTOMS	CHRONIC SYMPTOMS	DURATION OF SYMPTOMS	INITIAL THERAPY	PREOPERATIVE DIAGNOSIS	BACTERIOLOGY SPUTUM	LOCATION OF LESION
1	578636 L. K.	45	M	Paper mill	Acute onset of malaise, fever, cough, and rusty sputum	Cough, sputum, hemoptysis, and chest pain	2½ mo.	Penicillin	Carcinoma	Alpha hemolytic streptococci, staphylococcus albus	Right upper lobe
2	570222 H. L. C.	33	M	Woolen mill	Sudden onset of pleuritic pain, cough, fever, and sputum	Gradually subsiding pleuritic pain, cough, and sputum	2¾ mo.	Penicillin and sulfonamide	Empyema, collapse of right middle lobe	Alpha hemolytic streptococci	Right middle lobe
3	448275 J. N.	42	M	Teacher	Acute onset of chills, fever, cough, rusty sputum, and chest pain	Occasional slight cough	4½ mo.	Sulfonamide	Carcinoma	Not done	Right upper lobe
4	474136 G. H.	56	M	Real estate	Severe upper respiratory infection and later cough, sputum, fever	Cough, sputum, fever, hemoptysis, weight loss	4½ mo.	None	Carcinoma	Alpha hemolytic streptococci, anaerobic beta hemolytic streptococci	Right middle lobe
5	557172 S. D.	32	M	Student	Upper respiratory infection with cough and greenish sputum	Chest pain, cough, mucoid sputum, intermittent fever	4¾ mo.	Penicillin	Chronic pneumonitis	Alpha hemolytic streptococci	Right middle lobe

6	26496 L. C.	32	M	Dry cleaner	Insidious onset of "pressure in chest" followed by cough, white sputum, and night sweats	Cough and sputum	9 mo.	None	Carcinoma	Not done	Left upper lobe
7	484001 M. B.	12	F	Schoolgirl	Insidious onset of cough, white sputum, and slight chest pain	Cough and sputum	11 mo.	None	Chronic pneumonitis	Hemolytic and nonhemolytic streptococci	Right middle lobe and adjacent portions of upper and lower lobes
8	479566 J. C.	67	M	Bleacher	Weight loss followed by acute onset of fever, cough, and dark sputum	Cough and sputum	12 mo.	Sulfonamide	Carcinoma	Not done	Right lower lobe
9	553955 M. H.	57	M	Accountant	Insidious onset of malaise, cough, yellow sputum, and hemoptysis	Cough and sputum	12 mo.	None	Carcinoma	Alpha hemolytic streptococci	Right upper lobe
10	189995 H. S.	36	M	Woolen mill	Recurrent attacks of pleuritic pain, cough, and yellow sputum	Cough and sputum	5 yr.	None	Bronchiectasis	Pneumococci type 29, Friedlander's bacilli, beta hemolytic streptococci	Left lower lobe

but in five of them a diagnosis of pneumonia was made by the family physician. Two patients who were said to have had pneumonia received penicillin. Two received some form of sulfonamide medication, and one received both types of medication. None was greatly improved by such treatment and the condition settled into a chronic illness in all cases. Exacerbations and remissions of acute episodes characterized the course in the majority.

The principal chronic symptoms were fever, cough, expectoration and occasional hemoptysis, pleuritic pain, and weight loss. The symptomatology was sometimes very mild and one patient had no pulmonary symptoms. The duration of symptoms varied from nine weeks to five years, but nine of the ten patients had been ill one year or less.

The findings on physical examination were usually consistent with consolidation of a portion of the lung, but signs were sometimes absent. Roentgen-ray examination of the chest was helpful in the localization of the disease. A variable portion of the lung usually showed evidence of atelectasis or consolidation, and although the appearance sometimes suggested that of an inflammatory process, the possibility of carcinoma could seldom be excluded with any degree of certainty on the basis of the roentgen-ray examination alone.

Bronchoscopic examination usually showed no abnormality or at most inflammation of the bronchial wall. Bronchograms on three patients were not helpful since the lipiodol failed to enter the bronchi in the involved segments of lung. The sputum was cultured in seven of the ten cases but no unusual organism was identified. Cytologic examinations for neoplastic cells in smears of the sputum were made in two cases. The results were negative in both. The sputum was not examined for monocytes containing doubly refractive material. This procedure might prove to be useful when performed in conjunction with a search for malignant cells in the sputum.

In six of the ten cases a preoperative diagnosis of carcinoma of the lung was made but at operation it was possible in each to recognize the inflammatory character of the disease. The density of the pleural adhesions was such as to suggest long-standing inflammation. The inflammatory masses within the parenchyma were firm and rubbery and it was not difficult to be certain that the majority of such masses were not made up of neoplastic tissue, although the possibility of similar inflammatory masses occurring behind an obstructing neoplastic bronchial lesion had to be considered. In the majority of these cases there were large, firm chronically inflamed hilar lymph nodes. In two cases a biopsy of the inflammatory mass in the lung and of the adjacent lymph nodes was performed and the failure to find neoplastic involvement indicated that what appeared at first to be a massive tumor with metastasis to the regional lymph nodes was, after all, only inflammation. Resections were then performed with more confidence that a curative procedure was being carried out.

The technical difficulties in resection of this type of disease cannot be overemphasized. In one case the individual ligation technique was impossible because of inflammation about the hilum, and a tourniquet lobectomy had to be carried out. In addition to the inflammatory reaction about the hilus, in some

cases the pleural adhesions were of such dense and vascular character as to constitute a major technical difficulty. The duration of the disease had no relationship to the severity of the pleural or hilar inflammatory reaction.

The patients observed early in the series were given sulfadiazine both pre- and postoperatively and those observed later received penicillin. There were no postoperative complications. All these patients were completely relieved of their pulmonary symptoms and returned quickly to a normal state of health.

CASE REPORTS

CASE 1.—(M. G. H. No. 578636) L. K., a 45-year-old paper mill worker was in good health until nine weeks before admission to the Massachusetts General Hospital. At that time, after a three-week prodromal period of malaise, he developed an acute febrile illness characterized principally by generalized aching, fever, and nonproductive cough. He was admitted to his community hospital where he received parenteral penicillin and symptomatic treatment. While under treatment he began to raise approximately one-half cupful of brownish, occasionally bloodstreaked sputum daily. He also developed painful inspiration localized in the right upper anterior chest. Despite these changes he improved and was discharged after seven days of hospitalization. Four weeks later he was readmitted to the hospital because of persistent cough, expectoration, and chest pain. Bronchoscopy and bronchograms were reported as negative. After ten days' observation a diagnosis of carcinoma of the lung was made and he was referred to the Massachusetts General Hospital for further therapy. At that time he had lost twenty pounds in weight. Cough, expectoration, and chest pain persisted to the time of entry.

Family history was irrelevant. At the age of 7 years he had had pneumonia without known sequelae. Twenty-eight years previously he had influenza during the epidemic of 1919. Seventeen years before admission he worked for eighteen months in the digest room of a paper mill, being exposed to acid fumes. During the year preceding the present illness he had occasional sharp "pleurisy" pains in the right chest. There was no history of exposure to tuberculosis. He had not used oily nose drops.

On admission the abnormal physical findings were slight, being limited to the chest where there was increased vocal and tactile fremitus over the upper aspect of the right chest posteriorly. The temperature was normal.

Laboratory data including white blood cell count, differential leucocyte count, hemoglobin, urinalysis, serum nonprotein nitrogen, protein, chloride, cholesterol, and total fatty acids were normal. Sputum cultures grew a few alpha hemolytic streptococci and *staphylococcus albus*. No acid-fast bacilli could be found in smears of the sputum. Cytologic examination of a sputum smear for neoplastic cells was negative.

Retained lipiodol obscured details on roentgenograms made following admission. Earlier films, however, showed an area of increased density extending outward and upward from the hilum in the lower portion of the right upper lobe.

On June 25, 1947, right upper and middle lobectomies were performed. On opening the chest the lung was adherent over the lesion only. There were numerous large soft lymph nodes about the hilum. The mass in the right upper lobe was discrete and rubbery hard. There was only a partial fissure between the upper and middle lobes, and because of uncertainty as to the limits of the lesion, the middle lobe was removed also. The postoperative convalescence was uneventful. The patient was discharged eleven days following operation and has remained well during the past one and one-half years.

The pathologic diagnosis was chronic pneumonitis with an 8 mm. abscess cavity.

CASE 2.—(M. G. H. No. 570222) H. L. C. was a 33-year-old woolen mill worker. Five weeks before admission to the Massachusetts General Hospital this patient was awakened from sleep by a sharp pain in the right lower chest. This was accompanied by fever (102° to 103° F.) and cough productive of moderate amounts of brownish sputum. The pain subsided after

four hours, but the cough and expectoration continued. His family physician began sulfonamide therapy. Forty-eight hours following the initial attack the patient had another bout of severe pain in the right lower chest lasting two hours. The pain was aggravated by deep breathing. Following this the pain was noticed only while the patient was coughing. After ten days the expectoration and cough diminished, but a fever ranging between 102° and 103° F. continued. Four weeks after onset he was admitted to a hospital where he received parenteral penicillin. After five days of such therapy the temperature returned to normal. On April 11, 1947, he was transferred to the Massachusetts General Hospital. By that time he had lost forty-six pounds in weight.

Systems review, past history, and family history were noncontributory. He had not been exposed to tuberculosis. He had not used oily nose drops. A tooth had been extracted under local anesthesia one month prior to the present illness, but there was no history to suggest aspiration of blood or foreign body.

Abnormal physical findings were limited to the chest. There were dullness to percussion, diminished breath sounds, and diminished tactile and vocal fremitus over the right lower chest. The diaphragm was high on the right side with limited excursion.

On admission he had an irregular fever, varying between 99° and 103° F. The blood leucocyte count was 16,000 with 85 per cent polymorphonuclears, 12 per cent lymphocytes, 2 per cent monocytes, and 1 per cent eosinophils. Other laboratory data including red blood cell count, hemoglobin, serum nonprotein nitrogen, total protein, and chloride were within normal limits. The sputum culture yielded alpha hemolytic streptococci only. Sputum smears revealed no acid-fast bacilli. Cytologic examination of sputum smears for neoplastic cells was negative.

X-ray studies showed what was thought to be a cystic or abscessed right middle lobe, pleural fluid, and partial collapse of the right upper and lower lobes.

Thoracentesis revealed thin, foul-smelling pus in the right pleural cavity. Culture yielded *Staphylococcus albus* and *Haemophilus influenzae*. On April 26, 1947, thoracotomy and drainage of a small empyema cavity were performed. During the ensuing month the patient improved rapidly. He received penicillin parenterally throughout this period. The right upper and lower lobes re-expanded, but the middle lobe remained collapsed. Bronchoscopy at this time revealed a reddened, edematous right middle lobe bronchial orifice from which came considerable thin secretion. Bronchograms revealed normal right upper lobe bronchi and moderate dilatation of the right lower lobe bronchi. No lipiodol entered the right middle lobe bronchus.

On June 2, 1947, seven weeks after entry, a right middle lobectomy was performed. The entire right pleural cavity was obliterated by thin adhesions. The visceral pleura was markedly thickened. The middle lobe was reduced in size and firm to palpation. The reaction over it was more marked than in the remaining lung. The hilum was involved in a dense inflammatory reaction of such extent that individual ligation of hilar structures was impossible. A right middle lobectomy was performed by the tourniquet technique.

The postoperative convalescence was uneventful. The patient was discharged twelve days following operation. He returned to work one month following discharge from the hospital and has remained well since.

The pathologic diagnosis was chronic pneumonitis, cholesterol type. No abscess was found.

CASE 3.—M. G. H. No. 448275) J. N., a 42-year-old man, a schoolteacher, was well until four and one-half months before the present admission, when he developed chills, fever, cough, rust-colored sputum, and pain in the right upper chest. A diagnosis of pneumococcus (type 2) pneumonia was made. He spent five weeks in another hospital and made an uneventful recovery. Sulfonamides were administered without any noticeable improvement. There was no history of his having used oily nose drops or sprays.

Following discharge he remained well except for an occasional slight cough and a rather slow return of strength. He gained ten pounds in weight. There was no fever, sputum, hemoptysis, or other evidence of continuing infection. Three weeks before admission to the

Massachusetts General Hospital his physician obtained a follow-up roentgen-ray film of the patient's chest. This showed a persistent shadow in the right upper lung field. A bronchoscopy was performed and a biopsy of suspicious looking tissue was obtained. The pathologic report was "squamous metaplasia."

At the time of admission to the Massachusetts General Hospital he had no specific complaint except what he called "nervous stomach." This had developed when he learned that he might have serious disease in his lung.

A systemic review and past history were negative except that a tonsillectomy had been performed twenty years previously with an uneventful convalescence. There was no history of exposure to tuberculosis.

Physical examination was normal except for slight dullness to percussion and tubular breathing over the right upper lung field. There were no râles.

Laboratory data including urinalysis, white and red blood cell counts, hemoglobin, serum Hinton, and nonprotein nitrogen were within normal range. Roentgen-ray films of the chest revealed partial collapse of the right upper lobe, apparently in the posterior medial segment. Within the area of collapse there appeared to be several air-containing areas such as are seen in consolidation of the lung with an open bronchus. The right lower and middle lobes showed some compensatory overexpansion. The superior mediastinal structures were retracted toward the right. There were no evident hilar glands or pleural effusion. Bronchiogenic carcinoma was considered the most likely diagnosis.

On May 19, 1944, a right upper lobectomy was performed. The lower lobe was adherent to the diaphragm but not elsewhere. The upper lobe was closely adherent to the chest wall. The density of the adhesions suggested tuberculosis. The periphery of the lobe was dissected free with some difficulty. Once this was accomplished the operation proceeded without incident. There were no enlarged lymph nodes at the hilum.

The postoperative convalescence was uneventful and the patient was discharged fourteen days after operation. He has remained in good health since.

The pathologic diagnosis was chronic pneumonitis and slight bronchiectasis.

CASE 4.—(M. G. H. No. 474136) G. H., a 56-year-old real-estate agent, was in good health until four and one-half months before admission to the Massachusetts General Hospital. At that time he developed what was believed to be a severe upper respiratory infection. Two weeks later he began to cough up a moderate amount of rust-colored, foul-smelling sputum. After two weeks this diminished and the foul odor and purulent character disappeared. He had frequent low-grade fever and night sweats. On two occasions there was streaking of blood in the sputum. He had one twelve-hour episode of right lower chest pain. He had lost fifteen pounds during the four months preceding admission. There was no history of exposure to tuberculosis. He had not used oily nose drops or sprays.

Systems review and past history were irrelevant except for the fact that he had passed dark urine during the week prior to entry.

Physical examination was entirely negative.

Laboratory data including white blood cell count, differential white blood cell count, hemoglobin, and serum Hinton were normal. Two sputum smears stained for acid-fast bacilli were negative. Urinalysis showed a few red blood cells and white blood cells per high-power field in a centrifuged specimen and 1 plus albuminuria. The sputum contained abundant alpha hemolytic streptococci and a few beta hemolytic streptococci.

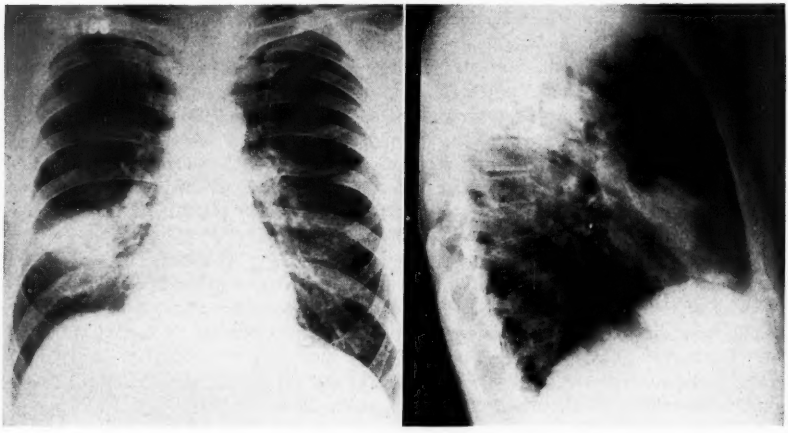
Roentgenograms of the chest (Fig. 1, *A* and *B*) revealed a sharply defined area of density in the lateral segment of the right middle lobe within which was an area of rarefaction which could have represented a small cavity. There was also a linear shadow of increased density overlying the left third interspace anteriorly and laterally. A differential diagnosis of carcinoma, abscess, septic infarct, or tuberculosis was considered. Intravenous pyelography prompted by the presence of red blood cells in the urine outlined a normal urinary tract.

Bronchoscopy revealed no abnormality.

A preoperative diagnosis of carcinoma of the lung was made and on Jan. 4, 1945, a right middle lobectomy was performed. The lobe had the gross appearance of tumor, but on palpation felt rather soft. The pleura was adherent peripherally and between the lobes. A biopsy and frozen section examination of suspicious tissue in the middle lobe revealed no evidence of malignant disease.

The postoperative convalescence was uneventful. The patient was discharged from the hospital ten days following operation. Since his discharge he has had no further pulmonary symptoms except occasional slight cough productive of a small quantity of "phlegm."

The pathologic diagnosis was acute and chronic pneumonitis.



A. *B.*

Fig. 1, *A* and *B* (Case 4).—Posteroanterior and right lateral roentgenograms of chest.

CASE 5.—(M. G. H. No. 557172) S. D., a 32-year-old student, was well until four and three-fourths months before admission to the Massachusetts General Hospital when he developed a respiratory infection, the most prominent feature of which was a hacking cough productive of whitish-green sputum. This continued without chills, fever, or chest pain until one month before admission. At that time he suddenly developed a sharp pain in the lower portion of the right side of the chest. The pain was so severe that he was unable to take a deep breath. A few hours later he developed a temperature of 102° F. At the same time the cough began to produce a moderate amount of rusty-brown sputum.

He was admitted to the college infirmary where, with the aid of roentgenograms of the chest, a diagnosis of pneumonia was made. He was given parenteral penicillin and became afebrile and symptom-free after four days of such therapy.

He continued to be asymptomatic except for right lower chest pain on deep inspiration until two weeks later, when he experienced a bout of coughing and raised some mucoid sputum. About the same time he developed a low-grade persistent fever. He was told that he had a collapsed right lower lobe.

Two weeks before admission to the Massachusetts General Hospital a bronchoscopy showed no abnormality except that there was white mucoid material exuding from the right lower lobe bronchus. Four days later he became more febrile and began to raise small quantities of purulent sputum. He had received penicillin through most of the illness.

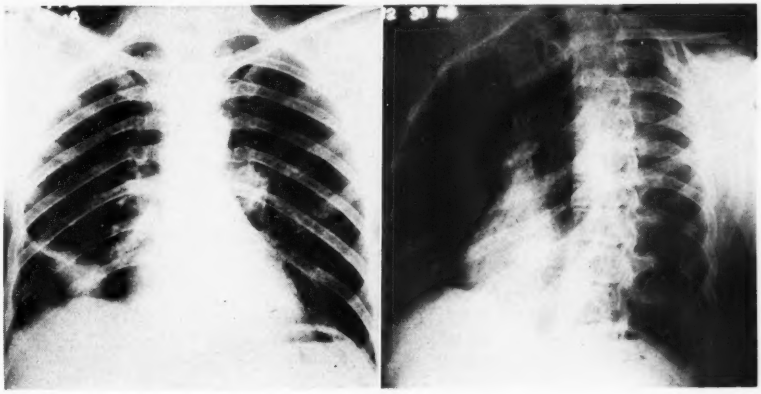
Systems review, past and family history were irrelevant except that his wife had chronic pulmonary tuberculosis. Oily nose drops or spray had not been used.

Physical examination at the time of admission to the hospital was negative except for a slight decrease of expansion of the right chest, diminished breath sounds, and a prolongation of the expiratory phase of respiration over the right lower chest posteriorly.

Laboratory data including white blood cell count, differential white blood cell count, hemoglobin, total serum protein, and serum nonprotein nitrogen were normal. Urinalysis was normal except for slight albuminuria, an occasional red blood cell, and 5 white blood cells per high-power field in the sediment of a centrifuged specimen. A single sputum specimen stained for acid-fast bacilli was negative.

Roentgenograms of the chest (Fig. 2, *A* and *B*) revealed an area of increased density in the medial segment of the right middle lobe. This appeared to be against the pleura, with a rounded margin directed toward the hilus. A more linear shadow was in the apex of the right middle lobe. This extended to the periphery and had a rounded margin. There was an area of emphysema in the anterolateral portion of the right lower lobe. The remainder of this lobe was rather markedly decreased in size. There was slight shift of the mediastinum to the right. Laminagraphy of the right main bronchus showed apparent narrowing of this bronchus without definite evidence of a tumor mass. A preliminary diagnosis of chronic pneumonitis was made, but the alternative diagnosis of carcinoma was considered.

Bronchoscopy showed a slightly reddened mucosa and a small amount of gelatinous secretion coming from the right middle and lower lobe bronchi. There was no evidence of obstruction.



A. *B.*

Fig. 2, *A* and *B* (Case 5).—Posteroanterior and right oblique roentgenograms of chest.

On Jan. 3, 1947, a right middle lobectomy was performed. On exploration of the chest there was no fluid and no evidence of pleural reaction except between the parietal pleura and the adjacent surface of the middle lobe where the lesion lay. These adhesions were obviously inflammatory but were readily freed. The middle lobe contained a firm mass which, however, did not feel sufficiently hard to be characteristic of carcinoma. The center appeared to be somewhat soft, suggesting the presence of a cavity. A right middle lobectomy was performed. The patient's convalescence was uneventful and he was discharged fourteen days after operation. He has remained well.

The pathologic diagnosis was acute and chronic pneumonitis.

CASE 6.—(M. G. H. No. 26496) L. C., a 32-year-old man, a dry cleaner, had no complaints until nine months before admission when he developed a "pressure sensation" in the left anterior portion of the chest. He consulted his family physician who obtained roentgenograms of the chest and gave him medicine which produced some relief. Four months after the initial symptoms he developed a cough productive of small amounts of whitish sputum. At about the same time he began to have frequent night sweats. He lost ten pounds in weight. There was no fever, hemoptysis, wheezing, dyspnea, or known exposure to tuberculosis. He received no special therapy. He had not used oily nose drops or sprays.

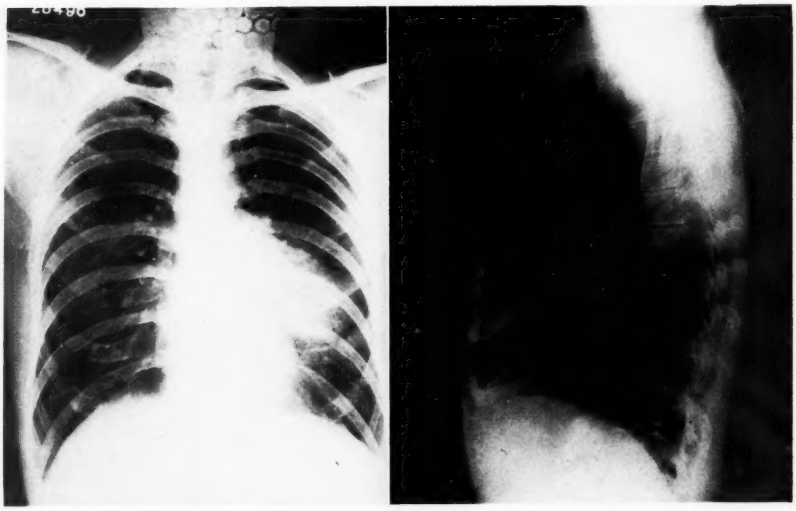
The past history and systems review were noncontributory.

Abnormal physical signs were confined to the chest where there were inspiratory râles and diminished breath sounds over the left scapular region posteriorly.

The white blood cell count was 13,100. The differential white cell and red blood cell counts and hemoglobin were normal. The red blood cells were moderately hypochromic and slightly microcytic. The platelets were increased in number. Urinalysis, serum Hinton, serum protein, and nonprotein nitrogen were normal.

Roentgenograms of the chest (Fig. 3, *A* and *B*) revealed an area of increased density extending from the left hilum downward, anteriorly and laterally in the region of the lingula. The left hilum was prominent and fluoroscopically masses were thought to be present within it. A roentgenologic diagnosis of carcinoma was made.

Bronchoscopy revealed only bronchitis on the left. No tumor was seen.



A. *B.*

Fig. 3, *A* and *B* (Case 6).—Posteroanterior and left lateral roentgenograms of chest.

On June 5, 1945, a left upper lobectomy was performed. The preoperative diagnosis was carcinoma. There were extensive adhesions between the lung and the chest wall. In the medial portion of the lingula there was an indurated mass which was densely adherent to the anterior chest wall. In the hilum of the lung there were several large soft lymph nodes. The tumor mass in the lung felt very much like carcinoma. A biopsy of the involved area, however, showed no evidence of malignant tumor. A lobectomy was performed.

The patient's convalescence was uneventful and he was discharged twelve days following operation. Recent examination revealed no evidence of abnormality and the patient has continued to work daily since his return home.

The pathologic diagnosis was acute and chronic pneumonitis.

CASE 7.—(M. G. H. No. 484001) M. B., a 12-year-old girl, was admitted to the Massachusetts General Hospital on April 5, 1945, complaining of a productive cough of eight months' duration. She was in good health until eight months before admission when she developed a cough initiated by a "tickling sensation" in the throat. This was thought to be a "summer cold." The cough soon became productive of small quantities of white mucoid sputum and shortly thereafter she began to complain of chronic fatigue. She did not gain weight at the usual rate. There were occasional brief periods of remission.

Two months before admission the cough became somewhat more severe and there were occasional paroxysms. There was no history of foreign body aspiration.

Systems review and past history were noncontributory.

Physical examination showed that the right diaphragm was elevated and moved only slightly. There were slight dullness and suppression of breath sounds over the right anterior lower chest.

The white blood cell, red blood cell, and differential counts were normal. There was 12.8 Gm. per cent of hemoglobin. Sputum and gastric washings were negative for tubercle bacilli. The sputum culture yielded abundant alpha hemolytic streptococci and occasional beta hemolytic streptococci.

Roentgenograms of the chest showed an extensive density occupying the region of the right middle and lower lobes. The right diaphragm was obliterated by the density in the right lower lung field. No diaphragmatic motion was seen fluoroscopically. The findings were considered indicative of collapse of the right lower and middle lobes.

Skin tuberculin sensitivity (O. T.) was negative in dilutions through 1:100. The blood sedimentation rate was twice the normal.

Bronchoscopy showed evidence of chronic bronchitis of the right middle and lower lobes.

On June 22, 1945, a right total pneumonectomy was performed. Preoperatively, the most likely diagnosis was believed to be chronic pneumonitis, with lung abscess as a second possibility. There were very dense and vascular pleural adhesions between the lower and middle lobes, the chest wall, the diaphragm, and the pericardium. The inflammatory process involved the entire middle lobe and the adjacent portions of the upper and lower lobes. A pneumonectomy was necessary for complete extirpation of the disease.

The postoperative convalescence was uneventful and the patient was discharged fourteen days after operation. Since operation she has had dyspnea on exertion and occasional bouts of nonproductive coughing attributed to mediastinal shift.

The pathologic diagnosis was chronic pneumonitis.

CASE 8.—(M. G. H. No. 479566) J. C., a 67-year-old bleachery worker, entered the Massachusetts General Hospital on Feb. 15, 1945, with a diagnosis of carcinoma of the lung. One year before admission he began to lose weight and in the ensuing six months lost sixty pounds. Seven months before admission he had spent six weeks in his community hospital where he was treated for "virus pneumonia." Sulfonamide therapy for several weeks did not alter the course of the disease. At the end of this hospitalization he was discharged with a diagnosis of unresolved pneumonia. Following discharge he developed a cough productive of one cupful of brown, nonodorous sputum daily. However, he felt well and continued his regular work. At no time did he have chills, fever, night sweats, or hemoptysis. There was no history of exposure to tuberculosis. He had not used oily nose drops or sprays.

Systems review and past history were noncontributory.

Physical examination revealed a chronically ill man showing evidence of considerable weight loss. The tongue was smooth and red. There was moderate clubbing of the fingers. The teeth were carious. Movements of the thoracic cage were limited on the right. There was an area of dullness and suppressed breath sounds over the right mid-lung field posteriorly. There were post-tussic râles over both upper lobes.

Urinalysis was normal. The white blood cell count was 9,500. There was 11 Gm. per cent of hemoglobin. Total serum protein, serum nonprotein nitrogen, serum chloride, and prothrombin time were normal.

Roentgenogram of the chest showed decrease in the size of the right lower lobe and a homogeneous density in the dorsal division, with linear strands of increased density in the lower portion. The right hilus was somewhat enlarged and low in position. The findings were considered suggestive of carcinoma of the right lower lobe bronchus.

Bronchoscopy was entirely negative.

On March 2, 1945, a right lower lobectomy was performed. The preoperative diagnosis was carcinoma of the lung. The right lung was densely adherent everywhere, especially over the lower lobe which was shrunken and partly collapsed. There was a small empyema cavity posteriorly, fluid from which on culture yielded Friedländer's bacillus. The inflammatory nature of the process was ascertained and a right lower lobectomy was performed.

The postoperative convalescence was uneventful and the patient was discharged twelve days after operation.

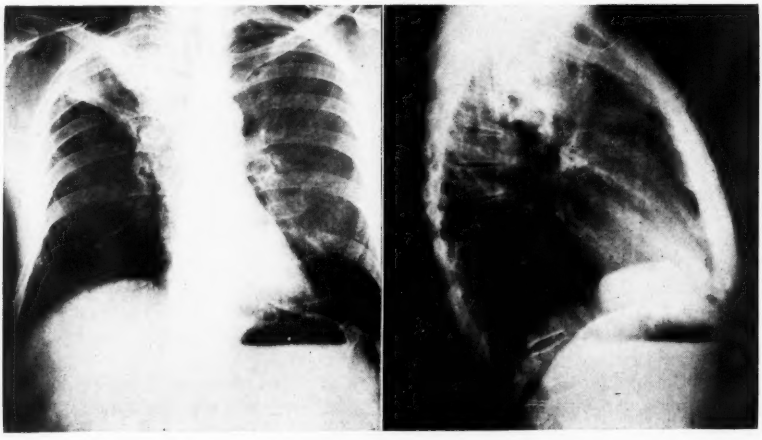
The pathologic diagnosis was chronic pneumonitis.

CASE 9.—(M. G. H. No. 553955) M. H., a 57-year-old man, an accountant, was well until one year before admission when he began to feel "slightly under par." This continued and although he had no specific complaint, he was aware of a gradual decline in health.

Two months before admission to the Massachusetts General Hospital he had a brief episode of right upper chest pain associated with paroxysms of coughing productive of small amounts of yellow sputum which was occasionally malodorous. On three different occasions he raised approximately one-fourth cupful of blood. He experienced infrequent episodes of sweating. There was a low-grade fever. His appetite remained fairly good, but he lost fifteen pounds of weight during the two months before admission. He received no specific therapy. He had not used oily nose drops or sprays.

The past history and systems review were irrelevant.

At the time of entry to the hospital physical examination revealed no abnormality except for a low-grade fever and the findings in the chest. Anteriorly over the right upper chest there were hyperresonance with slightly amphoric breath sounds and increased whispered voice. Posteriorly in a localized area over the right scapula there were slight dullness to percussion, fine to medium râles, increased and harsh whispered voice sounds, amphoric breath sounds, and increased tactile fremitus.



A. *B.*

Fig. 4, *A* and *B* (Case 9).—Posteroanterior and right lateral roentgenograms of chest.

The white blood cell count on entry was 16,400, with a normal differential count. The sputum culture revealed only alpha hemolytic streptococcus. No acid-fast bacilli were found in a single smear of the sputum. The prothrombin time was twenty-one seconds as compared with a normal of fourteen seconds. Urinalysis and serum Hinton were normal.

Roentgenograms of the chest (Fig. 4, *A* and *B*) showed a hazy mottled density throughout the right upper lobe which was moderately collapsed. The right hilus was elevated and there was a suggestion of a mass in it. The lung fields were otherwise clear. The appearance was considered to be consistent with that of carcinoma of the right upper lobe.

No tumor could be visualized by bronchoscopy, but removal of a mucous plug from the right upper lobe bronchus was followed by drainage of a considerable amount of bloody pus.

While awaiting operation he was given intramuscular penicillin, which produced a prompt subsidence of the fever.

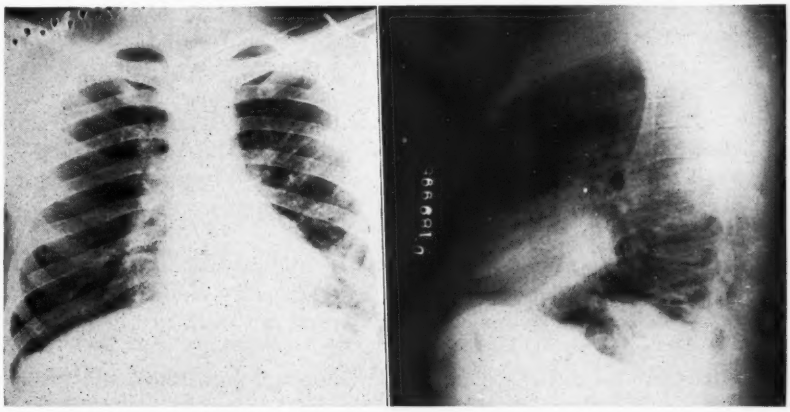
On Dec. 7, 1946, a right upper lobectomy was performed. The preoperative diagnosis was carcinoma of the lung. The upper lobe was adherent. The adhesions were of a subacute nature and could for the most part be readily separated by blunt dissection, leaving rather vascular oozing surfaces. There were enlarged lymph nodes in the hilum which were inflammatory in nature and there was nothing whatever to suggest carcinoma. It was, therefore, decided to perform a lobectomy only.

The patient's convalescence was uneventful and he was discharged thirteen days following operation. He has remained well since leaving the hospital.

The pathologic diagnosis was acute and chronic pneumonitis.

CASE 10.—(M. G. H. No. 189995) H. S., a 36-year-old man, a woolen mill worker, was well until five years before his first admission to the Massachusetts General Hospital, when he experienced the rather sudden onset of pain in the left lower chest. This persisted for a few weeks and gradually disappeared. The pain was aggravated by inspiration and he manifested a slight fever. Roentgenograms of the chest showed an area of hazy density at the base of the left lung obscuring the outline of the diaphragm and the apex of the heart. The appearance was that of an area of consolidation. He was treated for "pleurisy" by the application of a chest binder and rest.

He remained in good general health but complained of frequent "pleurisy pains" during the winter months. Two years following the initial episode he had another similar attack. Roentgenograms of the chest demonstrated a small triangular area of density at the base of the left lung. In the lateral view the costophrenic angle was obliterated by a small quantity of fluid. The findings were considered consistent with those of an infarct.



A. *B.*

Fig. 5, *A* and *B* (Case 10).—Posteroanterior and left lateral roentgenograms of chest.

In March, 1944, he experienced a third attack of sudden left lower chest pain which was associated with slight cough, sputum, and fever. He was admitted to the hospital for the first time.

Past history, systems review, and family history were noncontributory. There was no weight loss. He had used small quantities of oily nose spray off and on during the year preceding admission.

Physical examination was negative except for the chest. In the left lower chest laterally there were slight dullness, decreased tactile fremitus, diminished breath sounds, and abnormal vocal fremitus. On admission no râles or friction rub were heard, but later both signs were observed. The temperature on entry was 100° F.

The white blood cell count was 19,600. The sputum culture showed type 29 pneumococcus. Four sputum specimens were negative for acid-fast bacilli. Urinalysis, prothrombin time, clotting time, clot retraction, sedimentation rate, and serum Hinton were normal.

Roentgenograms of the chest (Fig. 5, *A* and *B*) demonstrated an area of increased density measuring 5 cm. in diameter occupying the left costophrenic sinus. The appearance was considered characteristic of an infarct. It was similar to that seen five years previously.

The patient was treated by bed rest and recovered in two weeks. The white blood cell count fell to 10,000 and the temperature was normal from the fourth hospital day on.

Roentgenograms of the chest taken two weeks following discharge from the hospital showed slight clearing of the process in the left lower lobe, although not enough to consider it the healing of an infarct. Lipiodol bronchograms obtained one month later revealed no positive evidence of bronchiectasis, but there was apparent obstruction of the terminal bronchi extending into the consolidated area.

The patient was readmitted to the hospital having had no further difficulty except that he had continued to raise one-fourth to one-half cupful of nonodorous yellow sputum daily. A preliminary diagnosis of bronchiectasis was made and a left lower lobectomy was performed on June 8, 1944. There were dense vascular adhesions between the lower lobe and the chest wall and especially the diaphragm. Marked inflammatory reaction and enlarged lymph nodes about the hilum complicated the dissection, but it was possible to deal with hilar structures individually in the usual manner.

The postoperative convalescence was uneventful and he was discharged thirteen days following operation. He has remained in good health since the operation.

The pathologic diagnosis was chronic pneumonitis.

DISCUSSION

Pulmonary resections for suppurative, neoplastic, and tuberculous disease have been performed with increasing frequency during recent years. There are relatively few references in the literature, however, which deal with chronic pneumonitis as a surgical problem. The most important contribution to the subject which has come to our attention is that of Freedlander and Wolpaw[3] who stressed the importance of the condition in the differential diagnosis of cases where carcinoma of the lung must be excluded. They very properly advocated early exploratory operation and the performance of a biopsy at the operating table.

Adams[9] recently reported briefly on ten cases apparently similar to ours both clinically and pathologically in which treatment was by surgery; five by lobectomy, two by pneumonectomy, two by drainage, and one in which only biopsy was done.

Thomas and Rienhoff,[10] Clagett and McDonald,[11] and Brown and Biskind[12] have each reported single cases in which resections were performed for chronic lipoid pneumonitis. Two of these cases simulated tumors and the other was associated with bronchiectasis. Clinically their cases were somewhat like ours, but aspirated oil has been excluded as an etiological agent in the present series by history and histochemical examination of the tissues.

The principal importance of chronic pneumonitis of the type described is that it may be confused with carcinoma of the lung. It has long been obvious that unless patients with pulmonary carcinoma can be operated upon in an early phase of the disease, the ultimate prognosis is dismal. In fact, if one feels obliged to wait until the diagnosis is proved by biopsy or is thoroughly obvious by roentgen-ray examination, the likelihood of effecting cures in very many cases is exceedingly slight. If progress is to be made in the management of carcinoma of the lung, therefore, an increased utilization of exploratory thoracotomy must be made in many doubtful cases.

On the other hand, at exploration the differentiation between neoplastic and chronic inflammatory disease may be difficult. Under such circumstances it is justifiable and necessary to perform frozen section biopsy examinations upon regional lymph nodes or actually upon pieces of lung removed from the suspicious area itself. This can be done with relative safety. As shown in two of the ten cases reported, this makes it possible to limit the operative procedure with more confidence to lobectomy instead of pneumonectomy. It is obvious, however, that a negative biopsy does not exclude carcinoma, for an inflammatory process similar to this may occur distal to a malignant lesion when there is bronchial obstruction. We have been unable to formulate any clear-cut criteria by which a differential diagnosis between chronic pneumonitis of the type described here and bronchiogenic carcinoma can be made preoperatively. The history combined with negative bronchoscopy and negative cytologic examination for neoplastic cells seem the most helpful factors in arriving at a correct diagnosis.

The ultimate fate of segments of the lung in which this type of chronic pneumonitis is seen remains somewhat uncertain. There is reason to believe, however, that exacerbations of acute pneumonitis, abscess formation, and ultimately the development of bronchiectasis may result. Surgical extirpation of these areas is therefore advisable when it becomes obvious that the condition has become chronic and irreversible. If a careful study of the lesion is made at the operating table, a correct diagnosis can usually be made, the proper operation performed, and the patient thus safeguarded against subsequent symptoms and disease.

PATHOLOGIC ASPECTS

In the beginning when only a few of these patients had been studied, the peculiarities of the condition under discussion were not fully appreciated. Our attention was concentrated on the eradication of presumed malignant disease of the lung, and the finding of a chronic pneumonia afforded a pleasing relief. At that time the comparatively early, more colorful phases of the process had not been encountered and the unusual features embodied in this pneumonia were not immediately apparent to us. With the acquisition of more material the changes in the pulmonary tissue could be arranged in sequence, but as no patient was subjected to operation less than two and one-half months after the onset of the pneumonia, only the late phases of the disease were observed. During this time the lung appeared to be occupied in disposing of a foreign substance, an effort repeatedly hampered by bacterial invasion. The nature but not the genesis of the foreign substance was determined during the study.

The gross and microscopic changes found in the lungs of the various patients were essentially similar, but different stages in the evolution of the process were encountered. It must be emphasized that one could not anticipate the condition of the lung from the apparent duration of the patient's illness. At times advanced pulmonary scarring had taken place a few months after the onset of definite symptoms.

The affected lobe was always decreased in volume. Fibrous adhesions of varying density were scattered over all the pleural surfaces and they were concentrated at the site of the underlying lesion, resulting in an appreciable thickening of the pleura at that point. The bronchial lymph nodes included with the specimens were several times the usual size and distinctly firmer than normal.

Fig. 6 (Case 2).—Complete consolidation of the middle lobe without bronchiectasis. The cut surface of the parenchyma was intensely yellow. The secondary lobules are outlined by thickened septa.

On section it was found that the pneumonic process had usually involved the entire lobe or the major portion of it. When the entire lobe was not diseased, the area of consolidation seemed to fan out from the hilum to assume a pyramidal shape with the base at the pleural surface. At least one pleural surface was always involved, and although the interlobar fissures were often obliterated by fibrous adhesions, the pneumonia had not penetrated the pleural membranes to involve an adjacent lobe except in Case 8, in which a pneumonectomy was performed. The specimen showed involvement of the entire middle lobe with extension of the process into adjacent areas of the adherent upper and lower lobes.

The cut surfaces of the lobes varied considerably in different patients. In the comparatively early stages of the process the most arresting aspect of the gross appearance was the intense yellow color of the diseased parenchyma. On closer inspection it was evident that this color was imparted by closely approximated, minute yellow dots (Fig. 6). As the pulmonary septa were thickened, glistening, and somewhat translucent, the secondary lobules of the lung were traced out in sharp definition. The primary lobules were often just discernible,

Fig. 7 (Case 10).—The lobe has been sectioned and laid open to demonstrate the late stage of the chronic pneumonitis characterized by fibrosis and patchy emphysema.

indicating that the air spaces were not entirely obliterated. In the more advanced stages of the pneumonia the gross appearance was that of an increasing fibrosis of the lung. The intense yellow color had faded and was replaced by a background of gray fibrous tissue lightly flecked with golden yellow dots that were sometimes segregated in areas of varying size throughout the lobe. Localized areas of emphysema were sometimes present in the fibrosed parenchyma (Fig. 7).

No obstructing lesion was ever found in the bronchial tree. The walls of the large bronchi were appreciably thickened and the mucosa was often red and granular, with prominent circumferential ridges; only borderline dilatation of the large bronchi was present in a small minority of the specimens. Sometimes a mucoid material was lying in the lumens. In the small bronchi with an approximate inside diameter of 1 to 2 mm. there was occasionally a marked dilatation of the lumen to 4 or 5 mm. This change was not uniform but occurred here and there throughout the area of pneumonitis and was accompanied by thinning of the bronchial wall and obvious destruction of its substance. The lumen at this point usually contained inspissated mucopurulent material. In four cases a small abscess with ragged ill-defined walls had formed in the lobe. These abscesses were never more than 1.5 cm. in diameter and they appeared to have originated from the destruction of a small bronchus and as a result of secondary infection.

Fig. 8 (Case 8).—Hemisection of the right lower lobe showing the sharp definition of the chronic pneumonia which fans out from the hilus and involves the pleura.

The border of the pneumonia, where it did not abut the pleura, was irregular but quite clearly defined and the surrounding parenchyma was emphysematous (Fig. 8).

Microscopic examination of the ten lobes showed a chronic pneumonitis in which the end result was an extensive fibrosis of the involved segments. In many of the specimens one could trace the gamut of changes from their inception to the replacement of the functional respiratory tissues by fibrous tissue. The lobes of patients with symptoms of long duration usually showed the more advanced stages of the process, but the picture was duplicated in a few individuals who had been ill for only a few months.

The earliest change detected in the parenchyma consisted of a flooding of the primary lobules by a great number of large mononuclear cells. The cytoplasm of the majority of these cells was occupied by fine droplets so that only a

mesh of lightly eosinophilic cytoplasm remained (Fig. 9). Occasionally the foamy cells assumed giant proportions and many nuclei were included in their substance (Fig. 18). Other large monocytes were not vacuolated, and of these a few contained cellular debris or a deep tan pigment, only a small portion of which gave a positive reaction for iron. The influx of these cells into the primary lobules was accompanied or followed closely by an inflammatory reaction in the interstitial tissue. The inflammatory reaction was ushered in by the appearance of edema, lymphocytes, and plasma cells in the peribronchial and perivascular tissue and, to a lesser extent, in the interlobular septa. These changes subsequently involved the alveolar walls and at this time the septal cells

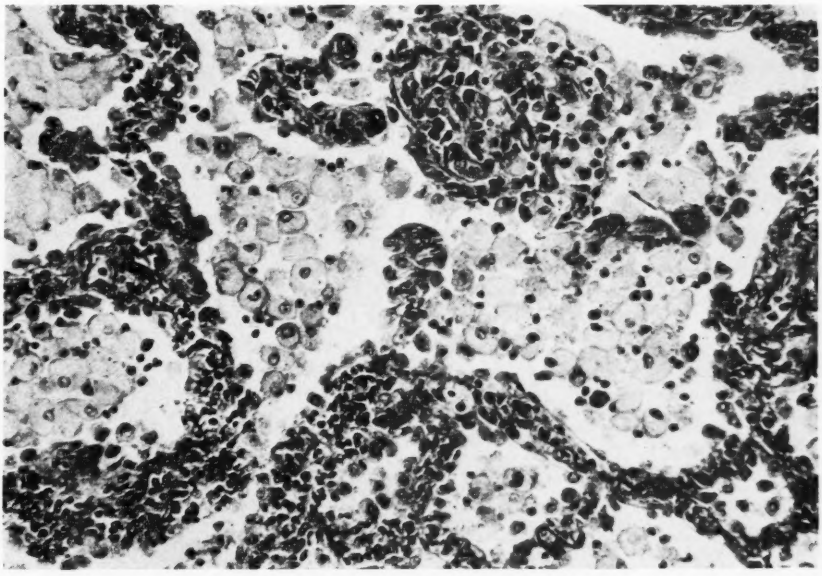


Fig. 9.—Flooding of the air spaces by vacuolated monocytes with the accompanying interstitial pneumonia.

of the alveoli had become greatly swollen and cuboidal (Fig. 10). The "epithelization" of the alveoli appeared to begin in the air sacs that abutted the interlobar septa, the pleura, and perivascular and peribronchial tissue, and gradually involved the remainder of the primary lobule. The alveolar lining cells were not vacuolated and often appeared to be desquamating into the air spaces. If they are the forerunners of the intra-alveolar foam cells, the vacuolation must take place after the cell has freed itself and is lying within the air space. The exudate within the alveoli, the alveolar ducts, and the respiratory bronchioles was now composed of large monocytes and a few lymphocytes, plasma cells, and neutrophiles; no fibrin and very little granular precipitate were present, and the neutrophiles were never vacuolated. At this juncture many aggregates of mature lymphocytes had formed in the interstitial tissues and

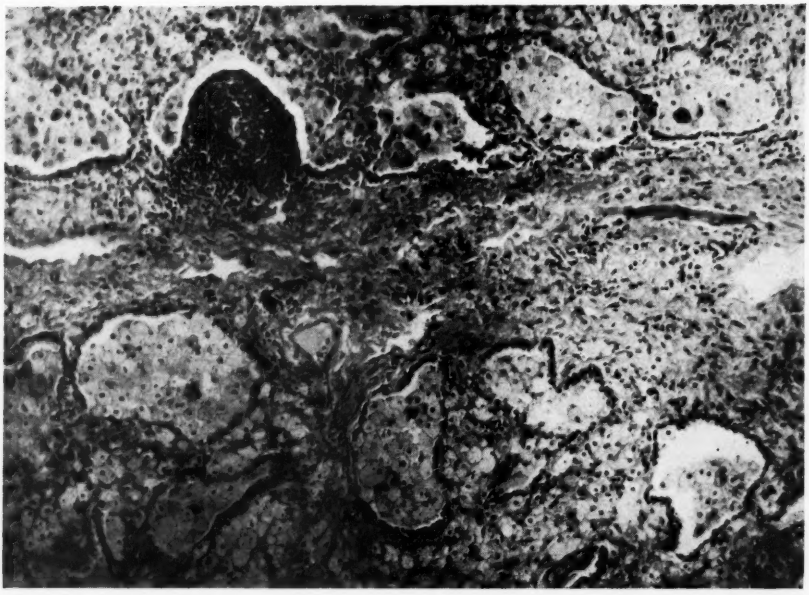


Fig. 10.—Swelling of the septal cells in the alveoli that lie against an interlobular septum.

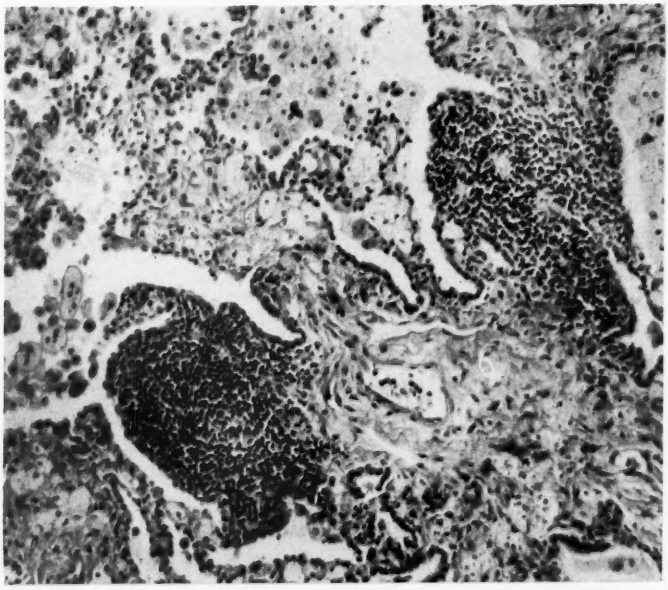


Fig. 11.—Aggregates of lymphocytes within the alveolar walls and budding into air spaces; they were covered by an unbroken line of septal cells.

budded into the air spaces, but were covered by an unbroken line of swollen septal cells (Fig. 11).

The next histologic feature of the chronic pneumonitis was the appearance and accumulation of the vacuolated macrocytes within the alveolar walls. The cells collected in such large numbers that the alveolar spaces were gradually obliterated and the primary lobules were reduced to the respiratory bronchioles and their branching alveolar ducts (Fig. 12). Occasionally large masses of foam cells obliterated the entire architecture of the lobule. In the presence of the chronic inflammatory reaction and the foam cells in the alveolar walls, a

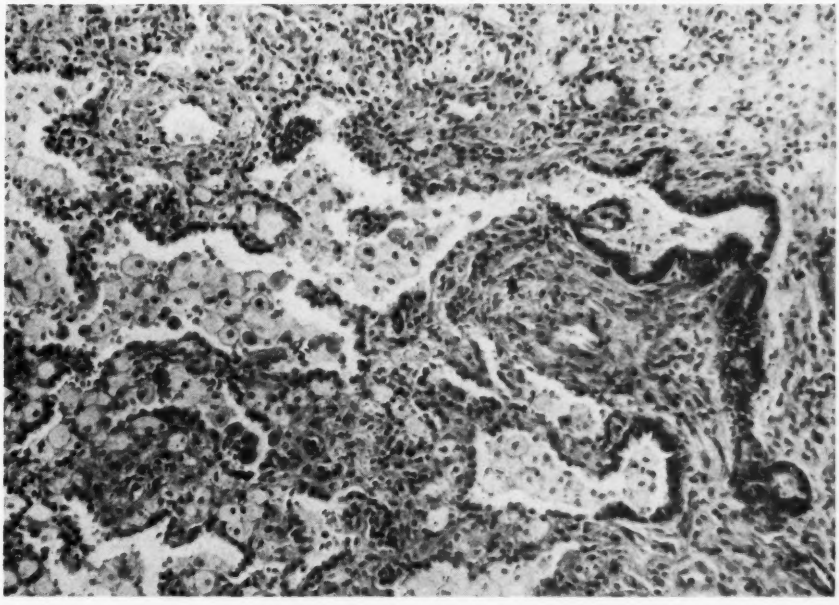


Fig. 12.—Obliteration of the alveoli by the accumulation of vacuolated macrophages within the alveolar walls. The respiratory bronchioles and alveolar ducts are not obliterated, but contain macrophages. A terminal bronchiole is seen on the right.

reticulum network was laid down which enclosed individual foam cells (Fig. 13). Later in the process collagen fibrils were deposited and the foam cells gradually decreased (Fig. 14). At this time vacuoles could be found in cells resembling fibroblasts. By this means the alveolar ducts were separated by broad bands of collagen that had replaced the foam cells, which in the beginning had obliterated the alveoli (Fig. 15). Often the alveolar ducts were isolated and choked off by the collagen (Fig. 16).

At the time when the interstitial tissue was flooded with foam cells and later when the interstitial collagen had increased, the foam cells were gradually cleared from the alveolar ducts. The obvious inference is that the foam cells migrated into the alveolar walls. However, many of them may have been cleared

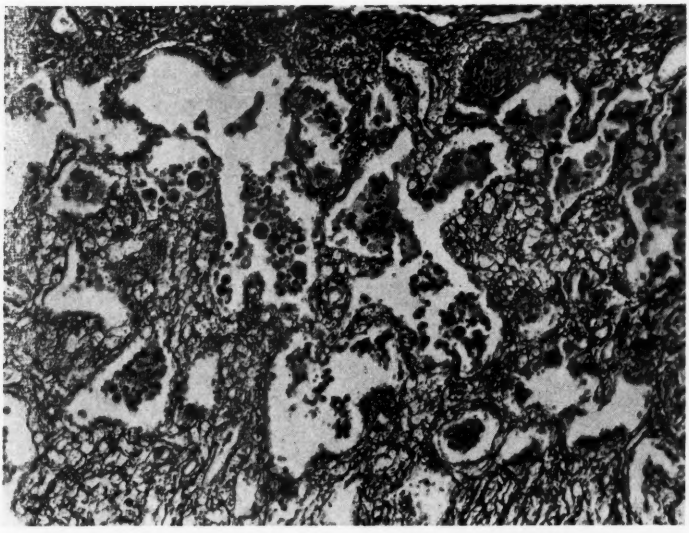


Fig. 13.—Silver impregnation to show the fine reticulum fibrils enclosing individual macrophages within the alveolar walls.

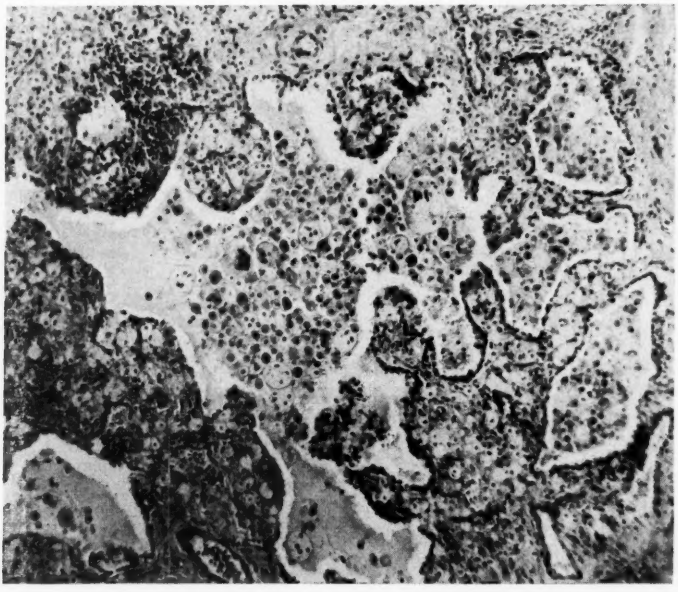


Fig. 14.—Beginning fibrosis of the alveolar walls and a decrease in vacuolated macrophages.

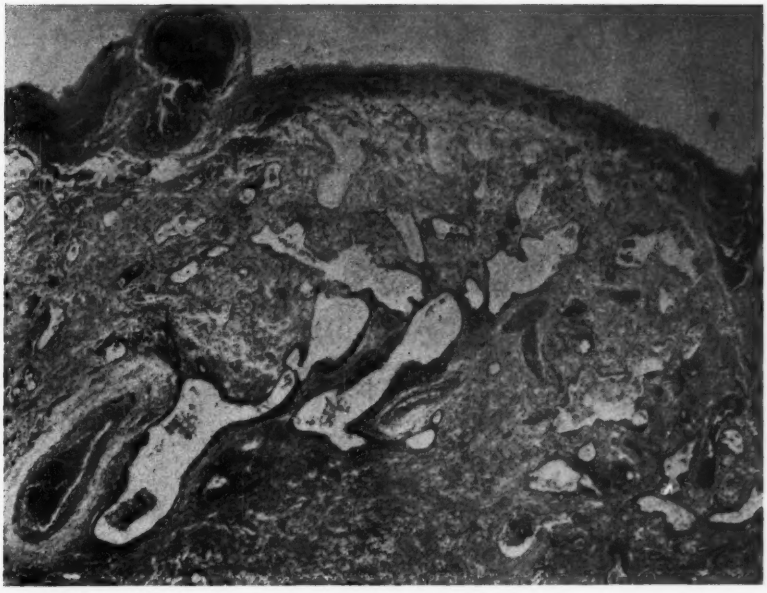


Fig. 15.—Fibrosis of a primary lobule; the dilated terminal and respiratory bronchioles and alveolar ducts still remain.

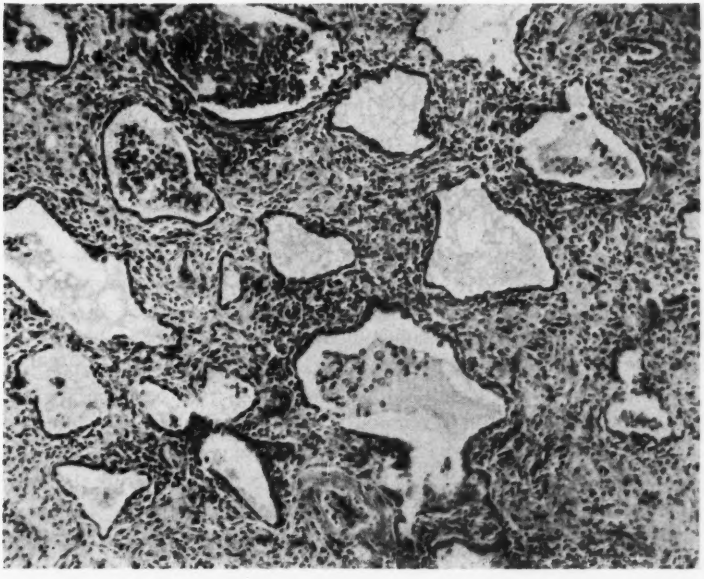


Fig. 16.—Isolation of the alveolar ducts by interstitial collagen. The ducts are lined by swollen septal cells but contain comparatively few vacuolated macrophages.

from the air spaces by incorporation in the sputum. Organization of the alveolar exudate did not take place except in the presence of what was presumably a secondary infection of the lobe. During the course of events the mild inflammatory reaction in the overlying pleura and in the interlobar septa gradually subsided, leaving these structures thickened and scarred.

The large bronchi throughout the area of pneumonitis often, but not always, showed a mild to severe infiltration by lymphocytes, plasma cells, and a few neutrophiles. Zones of squamous metaplasia and destruction of the wall were present but were not numerous and usually the epithelium was intact (Fig. 17). These changes were often present in the bronchioles, and at the end stage when fibrosis of the surrounding parenchyma had taken place, the terminations of

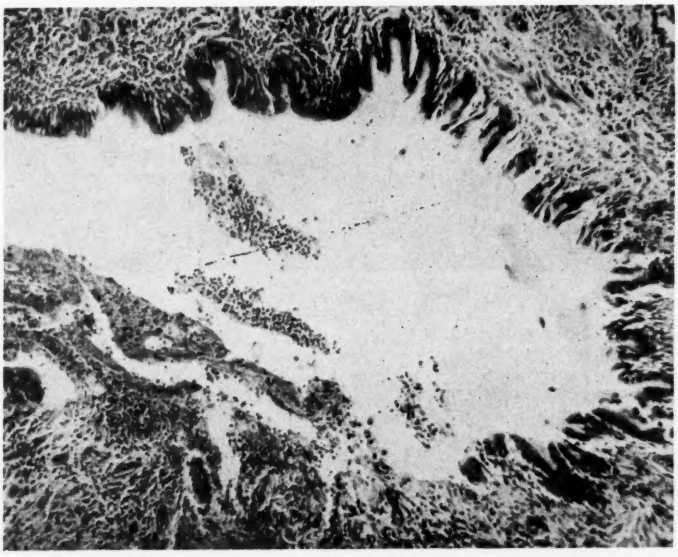


Fig. 17.—Acute and chronic bronchitis with ulceration.

the bronchi were greatly dilated (Fig. 15). Secondary infection of the bronchi seemed to be a fairly common event and consequently an acute purulent bronchitis was frequently superimposed upon the chronic process. In the presence of an acute reaction, necrotizing bronchiolitis was more frequent and, apparently because of this destruction, small abscesses had formed in the parenchyma of four of the specimens. Bacterial stains showed only very occasional gram-positive rods and cocci; unfortunately no cultures were taken from the lobes.

The histologic changes in the lungs appeared to center around the presence of the foam-filled monocytes or, perhaps more properly, around the substance within these cells. The origin of the monocytes in the alveolar spaces and walls may or may not stem from the septal cells which formed an unbroken lining for the alveoli and alveolar ducts. In experimental pneumonias of a somewhat similar character Ross[13] believes that the intra-alveolar phagocytes originate from

the connective tissue macrophages of the alveolar walls and that the cells lining the alveoli are not phagocytic. Various other opinions regarding the septal cells have been put forward by many authors.[14] In paraffin sections the substance in the monocytes was present in the form of fine vacuoles of uniform size (Fig. 18). The vacuoles filled and distended the cytoplasm of the cells and were sharply outlined by a delicate rim of lightly eosinophilic cytoplasm. The nuclei were small, deeply basophilic, and occupied the center of the cell or a somewhat eccentric position. They were never flattened against the cytoplasm membrane as in a fat cell. In brief, the monocytes were similar to xanthoma cells. The substances within the monocytes were believed to be largely cholesterol and

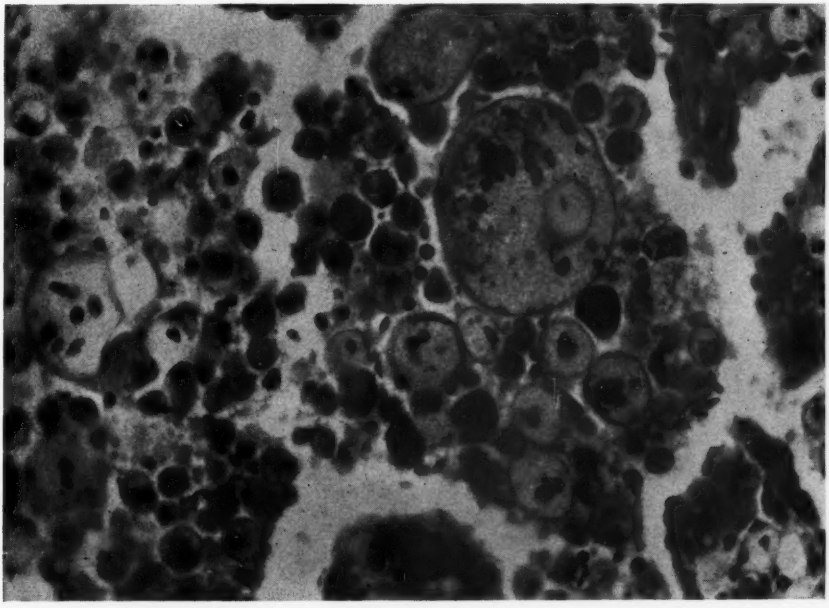


Fig. 18.—The cells of the alveolar exudate. The cytoplasmic vacuoles are finely divided and of uniform size. Several large multinucleated cells are present.

cholesterol esters for the following reasons. The intracellular material was intensely sudanophilic and doubly refractile, and with both these technics fine crystalline needles were found to be packed within the cytoplasm. Digitonin precipitation served to emphasize these qualities and in certain areas the material no longer dissolved sudan but remained doubly refractile, which was evidence that at that point no cholesterol esters were present (Fig. 19). Generally speaking, however, cholesterol and its esters were presumably too intimately mixed to allow a differentiation between them. The Schultz reaction for cholesterol and cholesterol esters was strongly positive.

Chemical analysis of tissue taken from grossly yellow areas of lung (fixed in formalin) in Cases 4 and 10 gave extremely high values for cholesterol and cholesterol esters. In Case 10 the cholesterol was twelve times and the cholesterol

ester eighteen times the normal. In Case 4 the cholesterol was twenty-nine times and the cholesterol ester ninety times the normal. Normal values expressed in milligrams per gram of wet tissue (fresh) were, cholesterol 0.3 and cholesterol ester 0.1.

The position of the extra-alveolar lipoid-containing cells is of some interest in regard to the lymphatic drainage of the lung. The cells occupied the walls of the alveoli and alveolar ducts and were soon surrounded by a network of reticulum fibrils and later by collagen fibers. Although the lymphatics of the lung are presumed to extend to the distal end of the alveolar ducts,[15] no foam cells were found in the lymphatic channels in any of the specimens. Open unobstructed lymph vessels containing a granular precipitate were identified in the bronchial walls, perivascular tissues, interlobular septa, and pleura. Furthermore, no foam cells were found in the bronchopulmonary lymph nodes, which were sometimes quite large but showed merely a nonspecific chronic lymphadenitis. Presumably, therefore, the macrophages were not removed from the lung by the lymphatic system.

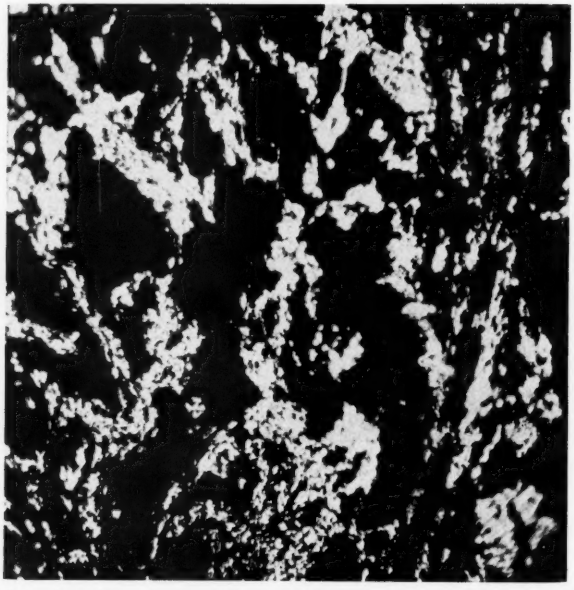


Fig 19.—Doubly refractile material outlining the alveolar walls (digitonin precipitation).

No vascular abnormalities were detected in the diseased parenchyma except in the later stages when perivascular fibrosis and endarteritic thickening became evident.

In brief, the condition under discussion is a chronic interstitial pneumonitis in association with large numbers of mononuclear cells containing cholesterol and cholesterol esters. The source of the cholesterol is not apparent. A type of pneumonia that is similar to this condition even in detail is encountered not

infrequently in the presence of bronchial obstruction from whatever cause. The frequency of this parenchymal change distal to stenosing lesions of the bronchus was pointed out to us by Dr. Robert Klopstock. A biopsy and frozen section of the peripheral portion of the lobe at operation is therefore of uncertain value to the surgeon in deciding his course of action, since the microscopic changes in the lung may be the result of bronchial stenosis due to such conditions as carcinoma or bronchial adenoma. In other chronic lung diseases such as bronchiectasis, lung abscess, and tuberculosis, small areas of "cholesterol pneumonitis" are sometimes found and are easily identified in the gross by the yellow stippling of the parenchyma.

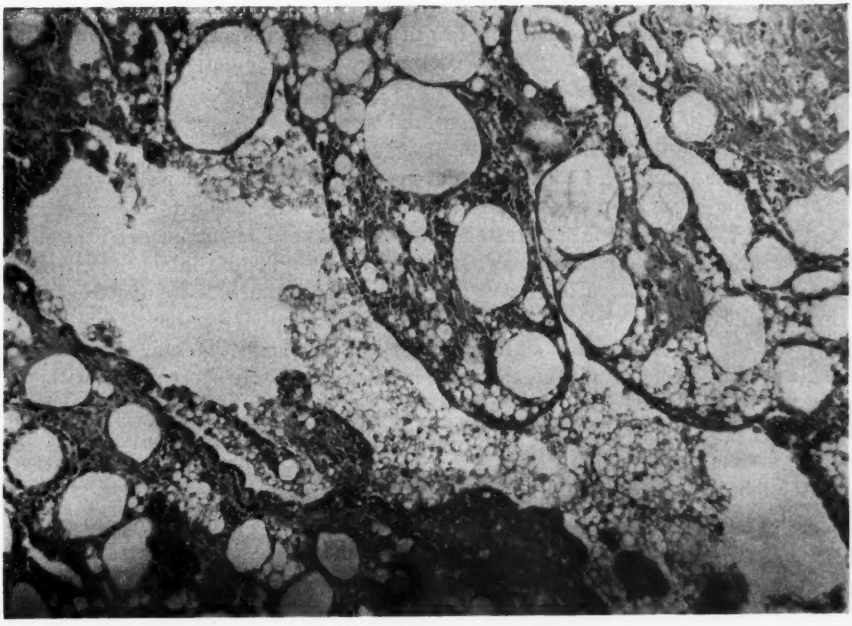


Fig. 20.—Oil aspiration pneumonia. Note the variation in size of the paraffin oil droplets and the coalescence to form large globules. The air space is an alveolar duct and the alveoli have been obliterated by the accumulation of oil-containing phagocytes within the alveolar walls. The nuclei of the phagocytes have been compressed against the cytoplasmic membrane.

The tissue changes in this lesion differ from those seen in resolving and organizing pneumonia following invasion by the pneumococcus or mixed bacteria. The mononuclear phagocytes of a resolving pneumonia often contain fine sudanophilic globules but very few of them are doubly refractile. Organization of the intra-alveolar exudate did not take place in this chronic pneumonitis in the absence of a superimposed acute pneumonitis. A striking similarity exists between the tissue reactions in cholesterol pneumonitis and in the pneumonia due to the aspiration of paraffin oil.[16-23] Freiman[24] has given us an opportunity of studying his cases of lipoid aspiration pneumonia and although the two conditions can be separated at a glance, in both, the position of the macrophages and the

interstitial reaction are the same. In paraffin oil pneumonia the size of the intracellular droplets is extremely irregular due to coalescence of the globules, and the nucleus of the host cell is flattened against the cytoplasmic membrane. Furthermore, paraffin oil is not doubly refractile nor as intensely sudanophilic as cholesterol. Nevertheless, paraffin oil excites a mild interstitial reaction with the formation of lymphoid aggregates, and the vacuolated macrophages accumulate in the walls of the alveoli and alveolar ducts with gradual obliteration of these air spaces (Fig. 20). When the macrophages lie in the interstitial tissues, they are surrounded first by fine reticulum fibrils and later by collagen fibers.[23] Thus, the background of the pictures in the two pneumonias is the same, but the substances within the macrophages differ. No acid-fast membrane bordering the monocytes could be demonstrated in the various sections as in the pneumonia produced by cod-liver oil.[18, 22, 23] With one exception the patients in this group said that they had not used oily nose drops or paraffin oil.

The possibility that the condition might represent a stage in the repair of a large "incomplete" infarct of the lung in which there is extensive intra-alveolar hemorrhage and edema without necrosis of the alveolar walls[25] was considered; the breakdown of the red blood cells would be a source of cholesterol. If this were the case, one should find zones of cholesterol-laden macrocytes at the border of a "complete" infarct where the alveolar walls are intact, but the air spaces contain disintegrating red cells. With this in mind a series of pulmonary infarcts in different stages of healing were studied, but there was no similarity between the two conditions. Furthermore, clinical and experimental observations indicate that incomplete infarcts resolve in a comparatively short period without the production of a chronic pneumonitis. The injection of blood into rabbits' lungs by Strassman[26] did not produce a pneumonitis and the erythrocytes were cleared from the alveoli within a few days. Gross and microscopic examination of the lobes in our cases did not disclose vascular occlusions.

A chronic interstitial pneumonitis with large numbers of monocytes in the exudate and swelling of the septal cells is seen in such conditions as primary atypical pneumonia[27-36, 42] and the pneumonia sometimes associated with measles,[37-40] variola,[41, 42] vaccinia,[41, 42] varicella,[43] lymphocytic choriomeningitis,[42] influenza,[39, 44, 45] and whooping cough,[46, 47] as well as the psittacosis-ornithosis group,[48-52] Q fever,[53, 54] and possibly rheumatic fever,[55-59] If dilute bacterial toxins[60] or vaccine virus[61] are injected intratracheally into experimental animals, the initial acute reaction is followed in several days by an interstitial pneumonia in which the exudate is composed of lymphocytes and monocytes and is accompanied by swelling of the septal cells. McCordock and Muckenfuss[62] by the simultaneous injection of vaccine virus and bacteria into the lungs of rabbits reproduced the pulmonary changes and attendant complications seen in the pneumonia of patients who had died during the course of influenza, measles, and whooping cough. A mononuclear and septal cell response is found in the lungs of patients at autopsy and in experimental animals after roentgen radiation to the thorax.[63-65] Geever, Neubuerger, and Davis[14] in a study of pneumonias occurring in a variety of conditions encountered at autopsy did not men-

tion intracellular cholesterol. A prominent feature in many of these pneumonias is the formation of a hyaline membrane lining the alveolar ducts.

No mention is made of intracellular cholesterol in the reports of these conditions, though occasionally "fat-laden" monocytes were seen. In MacCallum's report[44] on the pathologic anatomy of pneumonia associated with influenza, large numbers of fat-ladden monocytes were found in Cases 81, 87, and 91. These men died nineteen, eighteen, and forty-nine days, respectively, after the onset of the disease. Kay[66] studied ten lobectomy specimens from men who had developed bronchiectasis following atypical pneumonia. The lobes were resected six to thirteen months after the attack of pneumonia and the usual changes in bronchiectasis were found; no special features concerning the parenchymal reaction were mentioned. Intracytoplasmic and intranuclear inclusion bodies have been found in the respiratory epithelial cells in pneumonias presumed to be of viral origin.[29] Inclusion bodies were not found in the group of cases under discussion.

It is evident from this discussion that the pneumonitis which we have called colloquially "cholesterol pneumonia" has certain features in common with many other interstitial pneumonias due to a wide variety of agents, but it can be separated from these conditions by the remarkable deposition of cholesterol and cholesterol esters in the mononuclear cells of the exudate. Cholesterol pneumonia is found not uncommonly in the presence of stenosis of a major bronchus. In this group of cases bronchial stenosis could not be demonstrated by roentgenologic or bronchoscopic examinations, at operation, or after resection of the diseased lobe. It is possible that during the initial pneumonia which these patients suffered, a viscid exudate resulted in prolonged obstruction in the bronchioles thereby leading to their partial destruction and ectasia, and a chronic pneumonitis and parenchymal fibrosis of the secondary lobules beyond the obstruction. It is presumed from the evidence at hand that successive waves of secondary infection continually irritated the diseased parenchyma. Widespread necrosis of tissue or continued exudation of blood plasma into the alveoli are possible sources of the cholesterol, but tissue necrosis was not apparent in the diseased parenchyma, nor are similar changes found in chronic pulmonary edema. For the moment the origin of the cholesterol remains an intriguing mystery.

SUMMARY

Ten cases of chronic, nonsuppurative interstitial pneumonitis treated by surgical excision are presented in detail. The morphologic findings in the resected specimens are outlined and compared to other forms of long-standing pneumonitis, some of known etiology. A feature of the condition is the deposit within the pulmonary parenchyma of high concentrations of cholesterol and cholesterol esters. The origin of these materials and their bearing upon the pathogenesis of the pneumonitis are discussed.

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PULMONARY RESECTION FOR LUNG ABSCESS

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A REVIEW of the literature which has accumulated during the past ten years concerning abscess of the lung cannot fail to impress the reader with the seriousness of the disease. Valle,[1] in reviewing results in 244 unselected cases of lung abscess treated at Barnes Hospital, St. Louis, found an over-all mortality rate of 27.4 per cent. One hundred twenty cases treated at the Massachusetts General Hospital between 1938 and 1942 were studied by Sweet.[2] Of these 18.3 per cent of the patients were found to have died. A report from Charity Hospital in New Orleans of 417 cases showed death in 49.2 per cent.[3]

The work of Neuhof[4] advocating early one-stage transthoracic drainage for acute putrid abscess, along with the development of chemotherapeutic and antibiotic agents, has greatly improved the prognosis of the patient with acute pulmonary abscess. However, the mortality figures for the chronic form of the disease remain high, and of those patients recovering many are destined to go through life as chronic pulmonary invalids. Recently Shaw and Paulson[5] and Kent and Ashburn[5] have reported series of lung abscesses in which pulmonary resection, as well as open drainage, was utilized with significant reduction in mortality and increase in cure rate.

Overholt and Rumel[6] and R. L. Moore[7] have divided lung abscesses into two groups, the simple and the complicated, depending on the pathology present. We believe this classification to be a decided improvement over the usual chronological division into "acute" and "chronic." Briefly, the simple abscess is characterized by a single cavity unassociated with extensive pneumonitis, fibrosis, or bronchiectasis. The complicated abscess, on the other hand, may have several daughter abscesses, marked pneumonitis, fibrosis, and bronchiectasis. It is apparent that while adequate drainage of a simple lung abscess may result in cure, drainage of the major focus of a complicated abscess, with healing of that abscess cavity, still leaves significant pulmonary disease present, and the patient cannot be considered well.

PREOPERATIVE STUDY

There are three examinations which should be included in the preoperative study of all patients with pulmonary abscess. Accurate x-ray localization of the abscess cavity is of prime importance, regardless of the form of surgical treatment contemplated. In addition to the usual posteroanterior roentgenogram, lateral and oblique views should be obtained. If the presence of an abscess cavity is obscured by pneumonitis or pleural fluid, the mentioned views utilizing the Bucky technique should be included.

Bronchoscopy must be carried out promptly in all patients suffering from lung abscess. Since the pathogenesis of the disease is based on bronchial ob-

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struction and impaired bronchial drainage, the importance of bronchoscopic examination in determining the presence of an endobronchial lesion is obvious. Aid in localization of the involved bronchopulmonary segment by identification of the bronchial orifice from which pus issues may be obtained, as well as possible therapeutic benefit from evacuation of some of the pus.

Bronchography constitutes the third important examination and may be conveniently conducted by introduction of the iodized oil through a catheter inserted at the time of bronchoscopy. Obstruction occurring beyond the endoscopically visible areas of the tracheobronchial tree will be noted, and the presence of complicating bronchiectasis indicated. The bronchograms are also of aid in accurate localization of the involved bronchopulmonary segments.

ANALYSIS OF CASES

During the five-year period between September, 1942, and September, 1947, thirty-eight patients received pulmonary resection for lung abscess at Fitzsimons General Hospital. These patients were treated since the advent of the sulfonamide drugs, and after 1943 most of them also received penicillin. In all of the patients an attempt was made to utilize the individual ligation technique in the management of the hilar structures. In two instances this was found to be technically impossible and tourniquet resection was performed. Table I shows the anatomical location of the lesions treated.

TABLE I. LOCATION OF LUNG ABSCESS

Left upper lobe	9	Right upper lobe	9
Lingula	0	Right middle lobe	2
Left lower lobe	10	Right lower lobe	8

The equal frequency of upper and lower lobe lesions in the series, in spite of the more common occurrence of abscess in the lower lobes, may be explained by our willingness to resect upper lobe lesions whether simple or complicated.

In attempting to determine the etiology of the abscess in the cases reported, pneumonia was found to be the most frequent underlying lesion. Since the earliest x-ray manifestation of lung abscess is an area of pneumonitis, the significance of the postpneumonic group is questionable. Table II lists the etiology of the cases in this series as could best be determined.

TABLE II. ETIOLOGY OF LUNG ABSCESS

Postpneumonic	11
Trauma	5
Followed upper respiratory infection	4
Postoperative	3
Infected bronchogenic cyst	2
Vincent's angina	1
Pre-existent bronchiectasis	1
Amebic abscess of liver	1
Undetermined	10

Thirty-six of the thirty-eight patients had complicated lung abscesses. In many, of course, several complicating lesions were present. Bronchiectasis was the most frequent complicating factor, being present twenty times. Multiple abscess formation, extensive pneumonitis, and extensive fibrosis were also commonly noted.

TABLE III. COMPLICATING FACTORS

Bronchiectasis	20
Multiple abscesses	12
Extensive pneumonitis	11
Extensive pulmonary fibrosis	9
Bronchopleural fistula	3
Foreign body	2
Bronchoesophageal fistula	1
Sinus tract from liver	1
Empyema	1

Inquiry into the duration of symptoms prior to operation disclosed a range of from seven weeks to eleven years. The average duration prior to operation was one year.

TREATMENT

After the diagnosis of complicated lung abscess has been made and the diseased area adequately mapped, the problem of treatment presents itself. We feel that pulmonary resection is the treatment of choice. Ideally, this may be accomplished as the primary surgical procedure. However, if the patient remains toxic in spite of adequate antibiotic and chemotherapy and is felt to be a poor risk for extensive surgery, preliminary drainage of the mother abscess should be performed, with later resection when the patient is in better condition to withstand operation.

The management of upper lobe abscess presents a special problem, due to the inadequacy of bronchoscopic visualization of this area. A recent survey in this hospital showed that in less than 50 per cent of the cases of bronchogenic carcinoma was the primary lesion in a bronchoscopically visible portion of the bronchial tree.[8] This is of particular significance when one considers that various studies have shown that from 12 to 48 per cent of lung carcinoma shows evidence of cavitation.[9-12] Therefore, since bronchoscopic examination of the upper lobe bronchi is decidedly limited, we believe that lung abscesses occurring in the upper lobes should be treated by pulmonary resection, regardless of whether or not complicating factors can be demonstrated preoperatively. This is of particular importance in the management of patients in the middle and older age groups.

Of the thirty-eight patients in this series receiving pulmonary resection, five had had previous open drainage. Single lobe lobectomy was performed twenty-nine times, while in two patients two lobes were removed. In three cases the lesions were sufficiently localized to be removed by segmental resection. Total pneumonectomy was necessary in four patients.

The postoperative complications which were seen are listed in Table IV. Empyema occurred in five patients or 13.2 per cent of the total group. This is approximately three times as frequent as in our series of lobectomy for bron-

TABLE IV. POSTOPERATIVE COMPLICATIONS

Empyema	5
Postoperative pneumonitis	1
Drainage from site of previous open drainage	1
Transient pulmonary edema	1

chiectasis and may be attributed to increased difficulty of resection in abscess cases as well as to the disease itself.

There were three deaths in this series, a fatality rate of 7.9 per cent. Two of the three deaths occurred in patients undergoing pneumonectomy, one dying from pulmonary edema and acute cor pulmonale, and one from hemorrhage from the stump of the left pulmonary artery. The third death occurred on the eleventh postoperative day following lobectomy and was due to multiple brain abscesses and meningitis.

SUMMARY AND CONCLUSIONS

1. The preoperative examination of all patients with lung abscess should include accurate x-ray localization of the lesion, bronchoscopy, and bronchography.

2. Pulmonary resection is the treatment of choice in cases of complicated lung abscess and in lung abscesses located in the upper lobes.

3. A series of thirty-eight lung abscesses has been subjected to this management during the past five years, with a mortality rate of less than 8 per cent.

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Erratum

Concerning the article by J. R. McDonald, S. W. Harrington, and O. T. Clagett, on Obstructive Pneumonitis of Neoplastic Origin, in the February, 1949, issue of the JOURNAL, pp. 97-112, the authors wish it to be known that they intended to supply the name of Dr. Donald S. Morris on the manuscript or galley proof before the paper was published. They greatly regret that, by oversight, they failed in their intention.

A NEW FLEXIBLE DOUBLE-LUMEN CATHETER FOR BRONCHOSPIROMETRY

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THE first determinations of separate lung function in human subjects were made by Jacobaeus, Frenckner, and Björkman[1] in 1932. The apparatus used was a rigid double-lumen bronchoscope, introduced under direct vision and so positioned that air exchange to the two lungs was maintained through the respective channels of the bronchoscope; ventilation and oxygen absorption of the two lungs were recorded simultaneously. In 1934 Frenckner[2] greatly simplified the technic by altering and improving the double bronchoscope.

In 1936, Bezançon and his associates[3] made a number of observations, using a single-lumen bronchoscope, recording data first from one lung and then from the other. A great deal of technical difficulties arose in introducing these rigid bronchoscopes into the desired position. Also, the procedure was often very disagreeable to the patient.

In 1939, Gebauer[4] described a flexible soft-rubber double-lumen catheter, constructed for use in bronchospirometry. Independently of him Zavod[5] in 1940 described a similar catheter. These catheters simplify in some ways the procedure and make the examination less disagreeable to the patient. There is a flexible steel plate in the tip of the catheter and the capillary air leads are radiopaque. By means of fluoroscopy the catheter is placed in the correct position. In cases with marked distortion of the upper part of the trachea to the left, there are often difficulties in introducing the catheter into the left main bronchus. The usefulness of this type of double-lumen catheter is also limited by the small size of the breathing channels which it provides, and the increased respiratory effort entailed in "stenosis breathing" may amount to moderate or severe dyspnea sufficient to interfere with completion of the test. Furthermore, it is believed that in cases with marked disproportion between the ventilation of the two lungs, air exchange to the good lung is more restricted than that to the poor one. If this is true, the determination of the relative ventilation of the two lungs will be inaccurate. In patients with large amounts of viscous sputum it is often impossible to obtain satisfactory records because of obstruction of the channels.

To avoid this stenosis breathing Norris, Long, Oppenheimer, and Wester[6] in 1948 described a single-lumen catheter for use in simultaneous determination of separate lung function. The lumen of the catheter provides an airway to the left lung, and air exchange to the right lung is maintained around the catheter and through the larynx. The catheters (22-26 French), which have

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The catheter described in this paper was kindly made by Trelleborgs Gummifabrik, Trelleborg, Sweden.

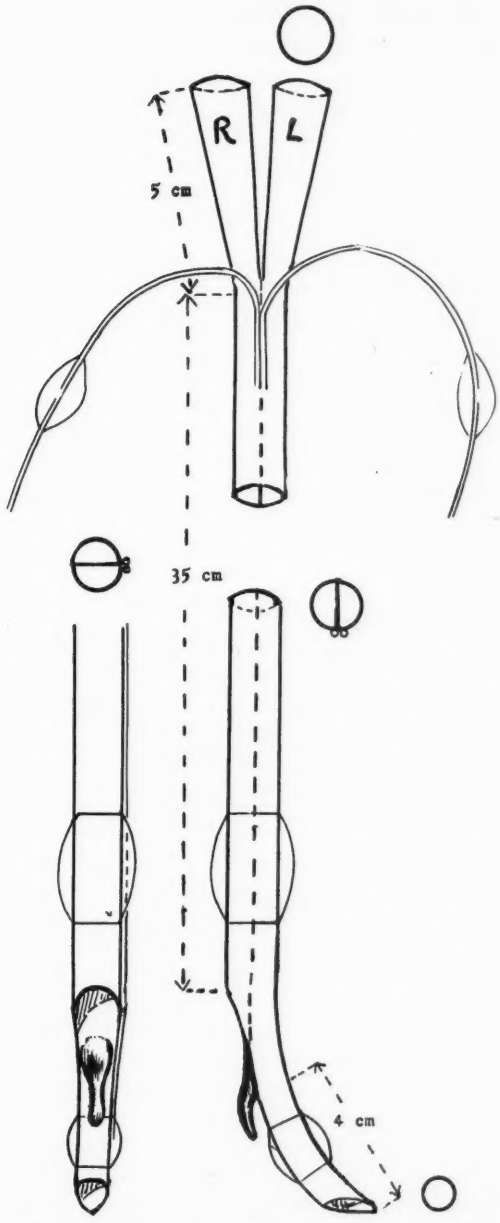

Fig. 1.—A flexible double-lumen catheter for bronchospirometry made in two sizes. The cross section is on the left side in the bronchial part circular and in the tracheal part semicircular. The area is the same in both (about 39 square mm. in the large size and 25 square mm. in the small size). The outer diameter is 13-14 mm. in the large size and 11-12 mm. in the small one.

an inflatable cuff, are of metal spiral construction and sheathed in latex Penrose tubing. The catheter is introduced on a curved stylet under mirror guidance and advanced into the left bronchus under fluoroscopic control. The outer end of the catheter is then brought through a Connell mask and through a rubber diaphragm in one arm of a Heidenbrinck Y-connector. The largest size of this catheter (inside diameter 7 mm.) offers a calculated resistance to air flow, which is approximately one fifth of that offered by one channel of the largest size of Zavod's double-lumen catheter.

I am convinced that the introduction of this method is of great value in bronchospirometry. Sometimes, however, there is, under the fluoroscope, difficulty in determining if the inflatable cuff is placed just between the carina and the mouth of the left upper lobe bronchus. In order to avoid this difficulty and to obviate the time-consuming procedure of fluoroscopy, we have constructed a flexible double-lumen rubber catheter of approximately the same rigidity as an ordinary urethral catheter. It is provided with a little hook that is automatically engaged by the carina. Fig. 1 illustrates the construction. The lumen of each channel in the largest model (that is, the one used in male adults) is the same size as the single-lumen catheter of Norris and associates. For women we use a somewhat smaller size with a diameter in each channel of 6 mm.

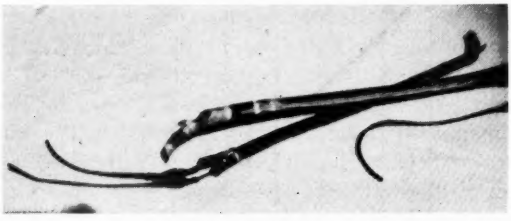

Fig. 2.—Photograph of the catheter manufactured in two sizes.

The Use of the Catheter.—Before the examination a curved metal stylet is introduced into the bronchial channel of the catheter. The rubber hook is tied down to the catheter with a silk thread in order to facilitate the introduction through the larynx. The knot is tied in such a way that it is easy to open when pulling on one end of the thread. The catheter is then introduced under mirror guidance. When the hook has passed the vocal cords, the stylet is removed and the knot is untied by means of a slight tug on the thread, which is then pulled out completely. The catheter is now turned 90 degrees to the left and it is gently pushed downward until the hook is engaged by the carina. It is very easy to feel when the catheter is in correct position. The cuffs are inflated with a syringe until the control bags on the upper part of the capillary air leads are distended. The capillary air leads are then clamped off. By observing the tension in the control bags, it has been easy to obtain the required distension in the cuffs. This has obviated the necessity for manometric control

of the pressure in the cuffs. The breathing channels are then connected with the twinspirometer and the examination may commence.

The catheter is constructed of rubber of moderate rigidity which makes it easy to handle. When it is being pushed down through the trachea, the bronchial end of the catheter exerts a slight elastic pressure on the left wall. It therefore automatically enters the left main bronchus even in those pathological states where the angle between the latter and the trachea approaches 90 degrees. The pressure exerted, however, is not so great as to traumatize the mucus membrane.

Premedication and topical anesthesia are approximately those employed for bronchoscopy. It is of great importance to give only a small dose of morphine in order not to depress the activity of the respiratory center. Otherwise, respiration becomes irregular and difficulties are encountered in measuring the oxygen consumption. For topical anesthesia the pharynx is sprayed lightly several times with a 2 per cent solution of pantocaine. The larynx, trachea, and larger bronchi are then anesthetized by fractional instillation of about 2 ml. of the same solution.

Employing this type of catheter, we have, during the last year, done over 60 bronchospirometric examinations and in no case has there been any difficulty in introducing it into the correct position. Nor have we seen any untoward effect from the procedure. After premedication with atropine or scopyl (metylscopolamine) we have never seen any obstruction by secretion, although in some instances we have continued the examination for as long as one hour. We have also been able to show that this catheter exerts almost no influence whatever on the respiratory movements. The summation of the vital capacities from both lungs has never by earlier methods with double catheters given the same result as obtained by ordinary spirometry. Especially with the rigid double bronchoscope the patients did not expire freely and there was a large amount of reserve air. With the flexible catheter of Zavod's type, a closer correlation was achieved but according to Pinner[7] it was necessary in the usual spirometric test to add a "stenosis" of the same magnitude as that produced by the introduction of the bronchial catheter in order to obtain a close correlation. Measured by our double-lumen catheter there is a very close correlation between the sum of the vital capacities from both lungs and

TABLE I. A COMPARISON OF THE SUMMATION OF THE VITAL CAPACITIES FROM BOTH LUNGS MEASURED BY OUR DOUBLE-LUMEN CATHETER AND THE VITAL CAPACITY OBTAINED BY ORDINARY SPIROMETRY IN SEVEN CONSECUTIVE CASES

PATIENT	VITAL CAPACITY			VITAL CAPACITY OBTAINED BY ORDINARY SPIROMETRY
	RIGHT LUNG	LEFT LUNG	RIGHT + LEFT LUNG	
H. S.	1780	380	2160	2010
F. V.	1250	390	1640	1720
G. H.	2780	2360	5140	5130
K. A.	1120	450	1570	1490
E. J.	1280	500	1780	1910
J. L.	490	920	1410	1500
A. G.	440	670	1110	1190

the result obtained from ordinary spirometry without any introduced stenosis. (See Table I). To get the conditions as similar as possible we have done the ordinary spirometry about a quarter of an hour after the bronchospirometric test before the anesthesia has disappeared.

We have also found that the lumina of the channels are large enough to permit bronchospirometric examinations on patients exercising on a cycle ergometer. This can be of great value in some cases in order to study the reserve capacity of oxygen absorption in an affected lung. These investigations are being continued and will be dealt with in a further publication.

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NOTICE

The Chairman of the Membership Committee of the American Association for Thoracic Surgery wishes to announce that applications for both associate and active membership must be received by him before Jan. 1, 1950. Applications received after this date will not be considered before the next meeting of the Association. All applications should be submitted to Dr. B. N. Carter, Cincinnati General Hospital, Cincinnati, Ohio.